

A CONFIRMATORY FACTOR ANALYSIS OF WRAML SCORES IN
A GROUP OF ACADEMICALLY TALENTED STUDENTS

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The purpose of this study was to confirm the original factor structure of the Wide Range Assessment of Memory and Learning (WRAML) utilizing a non-clinical adolescent population. Additional analysis examined the relationship between SAT-M scores and spatial relations ability. Exploratory analyses were conducted to determine ethnic and gender differences on the WRAML and subtests from the DAT.

Sixty-four academically talented adolescents completed the WRAML and the mechanical reasoning and spatial relations subtests from the Differential Aptitude Test (DAT). The confirmatory factor analysis found the data obtained to not be a good fit for the factor structure of the WRAML (Sheslow & Adams, 1990). Additional confirmatory analyses were conducted which examined data fit of a three factor model found by reanalyzing the standardization data (Burton et al., 1996; Wasserman & Cambias, 1991) as well as two null models. The data failed to fit any of these three models. No support was found for the second hypothesis that predicted a positive relationship between SAT-M scores and spatial relations ability. Ethnic and gender differences on the WRAML and two DAT subtests were examined and discussed. Limitations of this study were reviewed which may have accounted for the overall lack of results.

TABLE OF CONTENTS

	Page
LIST OF TABLES.....	iv
LIST OF ILLUSTRATIONS.....	v
Chapter	
1. INTRODUCTION.....	1
Academically Talented Youth	
Memory	
Information-Processing Model	
Level of Processing Model	
Dual Code Model	
Neuropsychology/Neurophysiology Influences on Memory	
Gifted and Memory	
The Wide Range Assessment of Memory and Learning (WRAML)	
Factor Analysis Research	
Attention	
Other WRAML Research	
Achievement Research	
Reading Achievement	
Math Achievement	
Mechanical Reasoning and Spatial Abilities	
Diffferential Aptitude Test (DAT)	
Scholastic Aptitude Test (SAT)	
Purpose	
Hypotheses	
Additional Research Questions	
2. METHOD.....	56
Subjects	
Materials	
Wide Range Assessment of Memory and Learning (WRAML)	
Space Relation Scale	
Mechanical Reasoning Scale	
Procedure	
Data Analysis	
3. RESULTS.....	66

Hypothesis 1	
Hypothesis 2	
Additional Research Questions	

4. DISCUSSION.....	75
APPENDICES.....	86
BIBLIOGRAPHY.....	92

LIST OF TABLES

	Page
1. Summary of Levels of Processing Model by Craik and Lockart (1972).....	12
2. Summarization of WRAML Factor Studies.....	30
3. Descriptive Statistics.....	67
4. Goodness of Fit Indices.....	68
5. Comparison of Each Confirmatory Factor Analysis.....	71
6. Breakdown of Mean Scores Between White and Non-White.....	73
7. Breakdown of Mean Scores Between Male and Female.....	74
8. Model Summary of Regression Analyses.....	74
9. Correlation Matric of WRAML subtests- (9 & older).....	89
10. Coefficient Alpha Medians Across Age and Person Separation Statistics for WRAML Subtests.....	91

LIST OF ILLUSTRATIONS

	Page
1. The Information Processing Model	10

CHAPTER I

A CONFIRMATORY FACTOR ANALYSIS OF WRAML SCORES IN
A GROUP OF ACADEMICALLY TALENTED STUDENTS

Academically Talented Youth

An abundance of information on the gifted and talented has been gathered throughout the years. Much investigation has been conducted looking at the personality patterns and cognitive abilities of such children. Janos and Robinson (1985) reviewed information on the personality of the gifted and talented student gathered from 1925 to 1985. They found consistent evidence of early psychosocial maturity among the gifted as well as a strong internal locus of control, self-sufficiency, independence, autonomy, dominance, individualism, self-direction, non-conformity, ambition, curiosity, exploration, and risk taking. Olszewski-Kubilius, Kulieke, and Krasney, (1988) in their review of the empirical literature, found talented students tended to be more independent, motivated, flexible, self-accepting, and psychologically well-adjusted as compared to same age counterparts.

Gifted and talented students have also been found to have a tendency for high achievement. Factors such as self-esteem have been found to be related to achievement in these youth. Hudes, Saladino and Miegler (1977), for example, found a significant relationship among giftedness, achievement, and self-concept in elementary students. Students with high self-

concept had a tendency to be high achievers and gifted as opposed to those with low self-concept who were more likely to be low achievers and nongifted.

Not all gifted are high achievers and various factors have been found to be related to underachievement of gifted youth. Personal or implicit theories of intelligence have been found important for predicting long-term achievement differences among academically talented students (Ablard & Mills, 1995). Beliefs regarding cognitive ability can vary from the view that intelligence is stable to the view that it is changeable. Ablard and Mills (1995) found approximately nine percent of their 153 gifted and talented students to be at risk for underachievement based on their self-perceptions of relatively low ability and the belief that intelligence is stable. Fear and/or avoidance of success has been reported to be related to underachievement in gifted youth (Tresemer, 1977). Overall, males and females appear to have similar fear of success effects (Romberg & Shore, 1986; Tresemer, 1976). Orlofsky (1981) found that for females this fear may be more of a lack of motivation toward and/or more ambivalence toward achievement.

It is generally accepted the gifted and talented student is independent, internally controlled, self-motivated, persistent, perceptually strong, task-committed, and nonconforming (Dunn, 1983). Many of these characteristics overlap (e.g., independence, internal control, and self-motivation) and seem to relate directly to persistence and task-commitment. Geiger (1992) found gifted youth as a whole showed an inclination to attend to internal ideas and concepts. It appears that internally controlled individuals tend to pursue an active, participative approach to

learning (Griggs & Dunn, 1984). Dunn (1983) feels it is the gifted child's perceptual strength which allows him or her to learn easily and perform well. Others, as well, have found that gifted children have well-integrated perceptual strengths (Barbe & Milone, 1982). This strength is believed to enable them to learn through varied learning channels, such as auditory, visual, tactile, and kinesthetic.

Van Tassel-Baska, Patton and Prillaman, (1989) point out that two of the most neglected populations within those who are defined as "gifted" are youth who are culturally different from the mainstream culture and youth who are socially and economically disadvantaged. From elementary through high school, there is a clear under-representation of minority students in gifted programs (Baldwin, 1987a; Ford & Harris, 1990). A study in 1989 commissioned by the Secretary of Education found that while minorities comprised 30% of public school enrollment, they represented less than 20% of the students selected for gifted and talented programs (U.S. Department of Education, 1989).

It is well known that programs whose purpose is to identify giftedness often under-identify such individuals in ethnically diverse populations (Baldwin, 1987a; Ford & Harris, 1990; Rhodes, 1992). Many claim it is overreliance on standardized testing which negatively affects the number of minority children being identified as gifted (Baldwin, 1987b; Cox & Daniel, 1983; Fatemi, 1991; McKenzie, 1986; Van Tassel-Baska et al., 1989). Extreme criticism has been raised for those who exclusively rely on such standardized test scores for

gifted identification (Bernal, 1990; Coleman & Gallagher, 1992; McKenzie, 1986; Reis & Renzulli, 1982; Sternberg, 1986).

Tapping the talents of all children would require a broadened vision of giftedness which would reflect the understanding that talent and creativity would vary markedly depending on cultural, ethnic, linguistic, or socioeconomic background (Ford & Harris, 1990; Hadaway & Marek-Schroer, 1992). Baldwin (1987a) finds creativity is often the dimension through which minority children express their exceptional abilities and many schools provide little consideration of creativity in their evaluation for giftedness.

Many complain that current definitions of giftedness are “elitist” and are based on restrictive, sometimes culturally biased criteria (Van Tassel-Baska et al., 1989; Woods & Achey, 1990). Test bias has often been cited as a cause of the low identification of giftedness among diverse ethnic groups based on the fact that it is difficult for students to qualify for a gifted program if the tests or other evaluation criteria do not reflect culture and experiences (Garrison, 1992). Gordon, Miller and Rollock (1990) point out that tests are highly ethnocentric, i.e., what is of value to one culture may be ignored or overlooked by another.

The issue of cultural bias in standardized testing has been controversial among professionals for some time (Ford & Harris, 1990; Gutkin & Reynolds, 1980). Many have noted that it is possible for such testing to contribute to the perpetuation of many barriers (social, economic, political) confronting ethnic minorities (Korchin, 1980; Scheuneman, 1979). Davidson (1982) believes that allowances must be made for cultural and educational diversity

for minority groups. Olmedo (1981) points out that testing, particularly standardized intelligence, aptitude, or ability testing, is inextricably intertwined with educational, social and economic opportunities in the United States. However, there are others who believe it has been the misuse of standardized tests rather than the test themselves that is responsible for the cultural bias against ethnic minorities (Novick, 1981; Gregory & Lee, 1986).

Specific criticisms of standardized testing include (a) measures are overly loaded with items based on White, middle class values and experiences, (b) measures penalize those with linguistic styles differing from that of the dominant culture, c) measures inspect cognitive styles directly opposed to those found in many low SES or minority children, (d) measures are often administered in an atmosphere that can penalize culturally diverse children (e.g., group administration), and (e) measures are scored based on norms from predominantly White, middle class standardization groups (Bailey & Harbin, 1980).

Another problem with accurate testing for the academically talented youth is the concept of multipotentiality. This idea is prevalent in the psychological literature in respect to the educational-vocational counseling of intellectually gifted individuals (Emmett & Minor, 1993; Kerr & Claiborn, 1991; Kerr & Colangelo, 1988; Kerr & Ghrist-Priebe, 1988; Milgram, 1991; Silverman, 1993). Fredrickson (1979) defines a multipotential person as “any individual who, when provided with appropriate environments, can select and develop any number or competencies to a high level” (p. 268). The problem arising for these talented youth is that they uniformly earn high scores across ability and achievement tests and exhibit multiple educational-

vocational interests at comparable intensities (Sanborn, 1979a, 1979b). Many believe multipotentiality affects most gifted students which results in a unique source of conflict and stress for them (Fredrickson, 1979, 1986; Jepsen, 1979; Kerr, 1981; Kerr & Ghrist-Preibe, 1988; Marshall, 1981; Sanborn, 1979a, 1979b). However, as Achter, Lubinski and Benbow (1996) point out empirical evidence supporting this is lacking. It appears that the idea of multipotentiality appears to rest primarily on unsystematic anecdotal evidence from counseling settings (Fredrickson, 1979; Kerr, 1981; Sanborn, 1979a, 1979b). Achter et al., (1996) also point out that the empirical investigations that have been done (Kerr & Erb, 1991; Kerr & Ghrist-Priebe, 1988) typically evaluate interventions for the “assumed problem” without first measuring the prevalence of multipotentiality in their sample.

Achter et al., (1996) investigated the concept of multipotentiality in an examination of over 1,000 intellectually gifted students in four separate cohorts. They were initially assessed at 12 or 13 years of age. College-level measures were used which included the Scholastic Aptitude Test, the Study of Values, and J. L. Holland’s (1985, as cited in Achter et al., 1996) six interest themes. Their results found profound individual differences among their sample in the variables relevant to educational-vocational choice. Less than five percent were found to have the high-flat ability, interest, and values profiles believed to be characteristic of the multipotentiality of gifted youth. These authors suggest the idea of these high-flat profiles comes from the use of age-calibrated (i.e., “developmentally inappropriate”) assessment tools that have insufficient ceilings for this population (p. 65). They believe the use of above-level assessment

devices and conservative criteria to define undifferentiated profiles can magnify ability-preference profile definition and help educational-vocational self-exploration for these youth.

Although there has been much criticism against the use of standardized testing for determining admission into gifted programs, it is still widely used. There are many who are calling for a redefinition of gifted (Baldwin, 1987a) as well as new or different instruments to better identify gifted and talented students (Hansen & Linden, 1990). The multipotentiality literature points out that the use of above-level assessment tools are needed and it is because of the use of age-calibrated assessment measure that the gifted have high-flat profiles (Achter et al., 1996).

Memory

The study of memory began in the 1800's. Hermann Ebbinghaus is credited with the first systematic research in this area. In his early work, he found it was easier to learn meaningful material than it was meaningless information. This finding became the precursor of mnemonics, a learning technique which creates meaningful information out of unrelated material. He later developed the decay theory or the theory of disuse to describe how information was lost or forgotten (Ebbinghaus, 1885). Results of his work suggested that the continued use of information (retrieval from memory) strengthened the memory pathway, while not using the pathway caused it to fade (i.e., forgetting).

Most of the early work on memory was conducted at the end of the last century and early in this century. The majority of these studies were limited to descriptions of developmental

trends. Schneider and Pressley (1989) reviewed this earlier research and gave the following summary: 1) immediate recall improves through school and continues increasing until about the age of 25; 2) performance on different memory tasks are affected depending upon age; 3) long-term retention declines once a certain age is reached; 4) sex differences are small or non-existent; and 5) memory performance is positively correlated to intellectual ability.

Later research began to look at the different techniques children used in developing memory strategies. Older children were found to differ in the use of mnemonic strategies as opposed to younger children (Kail, 1979). Results suggested that between ages of eight and 11, a child's strategy abilities become more consistent across different memory problems. Developmental changes marking increased mnemonic competence with age have been attributed in large part to increased proficiency in the use of learning strategies (Wasserman & Cambias, 1992). Research points to a reasonably consistent developmental trend in a child's use of strategies employed to aid memory (Kail & Hagen, 1982). For instance, there is an infrequent use of such strategies among five and six year olds. They do not rehearse material or organize stimuli, nor are they able to use cues to help remember. From seven to 10, there appears to be a transitional stage when memory strategies can appear. This depends, however, upon factors related to the strategy itself and to the context in which the strategy is to be used (Kail & Hagen, 1982). The first indication of strategy use generally appears approximately at 10 years of age. Children first begin to rehearse material, followed by deliberately organizing stimuli in terms of membership in conceptual categories, and finally they develop the ability to use

category cues to help them retrieve information. During adolescence, youth become increasingly flexible in their use of strategies, tailoring them as necessary to fit a memory problem.

Although there is a plethora of research in memory, to date there is not a universally accepted model of memory. Many feel current theories fail to explain how memory develops and functions (Cowan, 1988, Kail & Hagen, 1982) or how it is altered as a result of trauma, disability, or old age (Squire, 1987). Since the mid-1960's, the dominant view of memory has been one which holds there is a dynamic relationship between cognition and memory. Most agree there are internal processes of memory, e.g., different ways of coding, manipulating, and retrieving information (Bower, 1975). This dynamic model of cognition allowed for memory to be seen as an active process that could be divided into a series of stages.

The "information processing model" by Atkinson and Shiffrin (1968) was the first model to provide a reasonably detailed description of the major components of memory. Research spurred by this model, later produced the "levels of processing" model by Craik and Lockart (1972). Later research looked at differentiation between verbal and visual memory processes, i.e., "dual-code" theory (Paivio, 1969, 1971). A description of each model follows.

Neurosurgery has also contributed to the research into memory. There appears to be a wide variation in memory deficits indicating several areas of the brain are involved in the memory process. A short summary of this research follows as well.

Information-Processing Model. This model conceptualizes memory as divided into three structural or physical components: sensory register, short-term store,

and long-term store (see Figure 1). All memory is ultimately dependent on the “control processes” or mental strategies that are utilized (Shiffrin & Atkinson, 1969). These processes or strategies include attention, rehearsal, organization, elaboration, and reconstruction.

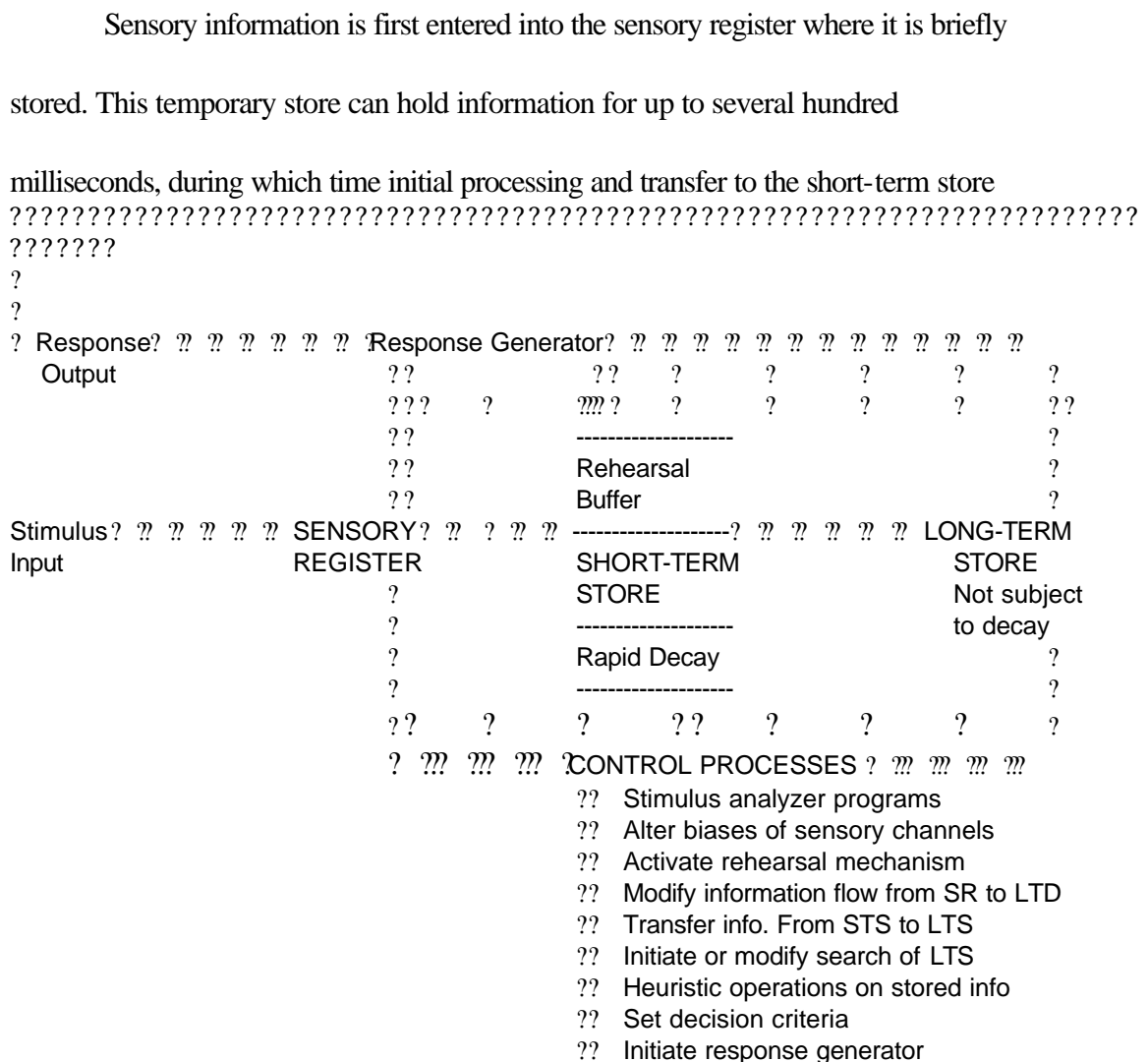


Figure 1. The Information Processing Model of Memory (Atkinson & Shiffrin, 1968). Arrows indicate paths of information transfer. Dashed lines indicate connections for information comparison and paths for control processes to be sent along.

may take place. This time appears to be critical to attention because the individual may or may not notice and attend to stimuli (Mealer, 1994). If the stimuli is not attended to, it may enter the sensory register but not be processed at a level sufficient to facilitate the move to short-term memory (Craik & Lockhart, 1972). If information is attended to, it is then selectively transferred to the short-term store, also called the working memory. This component has limited storage capacity. Information begins to decay after approximately 30 seconds, unless a strategy for retaining the information is implemented. Further processing involving rehearsal and other control processes allows the information to move to the long-term store or long-term memory. This latter component is hypothesized to be permanent and unlimited (Shriffin & Atkinson, 1969). Once the material has been transferred to long-term memory, it is accessible and enduring, although problems in retrieval can occur.

The flow of information from each store is controlled by techniques the individual uses to remember items (e.g., attention, rehearsal, etc.). It is believed these “control processes” give the system flexibility and allows for changes in memory function across development (Kail & Hagan, 1982). The emphasis on these mental strategies has been found to be consistent with later developmental studies which focused upon the youth’s understanding of the memory process, as well as the knowledge base brought to a memory problem, and the child’s strategies for memorizing (Brown, 1975).

Atkinson and Shiffirin’s model of memory was criticized as being very linear, with little flexibility for application (Hainlen, 1994). The model did not account for how recognition

occurred between the sensory register and the long-term store. Criticisms also included that the model was relatively vague about what was exactly the “information” being transferred from the short-term store to long-term memory (Bower & Hilgard, 1984). The information-processing model of Atkinson and Shiffrin (1968) was later expanded to include additional processing and has become what is now known as the “levels of processing” theory. The basic idea is that short-term or long-term storage is not so much a place where information is stored, but rather a method of processing (Bower & Hilgard, 1984).

Levels of Processing Model. Craik and Lockhart (1972) attempted to include the interactive nature of memory in their model instead of only viewing memory as the passive movement of information from input to output. They challenged the idea that information is transferred from one fixed system to another. Their model focused on a “process approach” where information is processed along a dimension called depth (see Table 1). By the end of the 1970’s, this levels of processing model had replaced the Atkinson and Shiffrin (1968) model as the dominant memory framework (Kail & Hagan, 1982).

Table 1

Summary of Levels of Processing Model by Craik and Lockart (1972)

	Stimuli	Rehearsal	Coding/Maintenance
Shallow processing	simplistic, concrete specific types: identify dog barking	maintenance; keeps information at same level	phonetic, less likely to be retained

Deeper processing	more complex, abstract stimuli: gather semantic meaning	elaborative; allows information to be stored at deeper levels	semantic, more likely to be retained
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Incoming stimuli enters through the senses and is then analyzed according to the depth of the information received. For simple, concrete, and specific types of input, shallow processing is required. Simple matching and associations are functions of shallow processing (e.g., identifying a dog that is barking). To analyze more complex, abstract, or semantic information, deeper processing is required. Gaining meaning from a complex reading passage is an example of deeper processing. Properties of the stored material were believed to be determined by the processing method rather than the storage location itself (Craik & Lockart, 1972).

Craik and Lockart (1972) believed that information, which was processed at a deeper level, was more likely to be retained than information which was only processed at the shallow level. These researchers proposed two types of rehearsal. Maintenance rehearsal was simply repeating the information, focusing on the phonetic aspects of the stimuli. This type of rehearsal kept the information stored at the same level. To encourage processing at a deeper level, rehearsal had to be paired with elaboration. This elaborative rehearsal emphasized the semantic attributes of the material and was associated with information that was already stored in long-term memory (Wickins, 1984).

This model purports that one develops a cognitive code of the physical stimulus (Dodd & White, 1980). For immediate reproduction and retrieval, a phonemic or articulatory code is used (i.e., focusing on the phonetic aspects of the stimulus). However, if the coding is subjected to more lasting coding, e.g, semantic coding, it was then more accessible over a longer retention interval. These codes can then be transformed, abbreviated, or elaborated (Best, 1995), since all information is subjected to a range of analyses from shallow processing to abstract processing. Elaborative rehearsal aided in the development of additional codes which could then facilitate future retrieval of information (Wickens, 1984).

Once a stimulus had been recognized, the possibility of analysis at a deeper level allowed for the information to be further enriched, elaborated, or transformed by past associations and experiences. Memory was thus seen as a continuum from temporary products of sensory analysis to lasting products of intense cognitive processes (Craik & Lockart, 1972). One's past knowledge and experience, learned rules, and other "information processing operations" then allowed information to be more effectively handled and retained. Developmentally, the model is consistent with the hypothesis that as children age, they attain greater control and flexibility over the activation of deeper levels of processing (Boyd, 1988).

The levels of processing model has at times been criticized for being vague (Hainlen, 1994). Best (1995) points out that research supporting this model is contradictory. However, there has been empirical support for this model as well as for the information processing model, which led researchers to question if it was possible for both models to exist for different types of

memories. This spurred more research as the field began to look at different memory processes. Investigation into how information was coded began to look at visual and verbal memory processes. For example, temporal differences were found between visual coding, auditory coding, and semantic coding (Solso & Short, 1979) and research into different types of memory proliferated.

Dual Code Model. It was suggested that information presented for memory encoding and storage may be processed differently either through visual processes or by verbal means. Paivio (1969, 1971) found that information was retained at a significantly higher rate when it was presented both visually and verbally. His dual code theory states that verbal and visual material may be stored in both short and long term memory, but the processes by which they were encoded and stored may differ. For example, verbal material may be acoustically represented in short-term memory as well as semantically related in long-term store. Visual material may be represented through an “analog” having the same visuo-spatial properties as the objects being represented. Paivio (1969, 1971) believed memory to work best when the verbal and the visual or analog systems were both used for encoding. For example, pictures are more likely to be remembered because they can be visually represented in analogue form as well as verbally represented through semantic association.

Depending upon the stimulus, visual memory can be better than verbal memory and vice versa (Paivio, 1971). Visual memory appears to be inferior to verbal memory when the stimuli is words. The visual code is superior only in the storage of concrete (object) information, e.g.,

viewing pictures or indirectly (i.e., associatively) by concrete words. Moreover, visual memory is superior only when immediate memory for temporal or sequential information need not be retained. Verbal memory has been found to be superior in sequential processing because it is specialized for sequential processing, whereas visual memory is not (Paivio, 1971).

Developmentally, there appears to be a gradual reduction in the dominance of visual memory that is observable from the preschool through the grade-school years (Schneider & Pressley, 1989). As one ages, the role of the verbal memory system increases, however, both systems are utilized throughout the lifespan.

Neuropsychology/neurophysiology influences on memory. In assessing those with a brain injury, it has become apparent that several areas of the brain are involved in the memory process. Memory deficits from neurosurgery were the first results to emphasize the structural concept of how memory was believed to be divided (Scoville & Milner, 1957). Evidence has been found for discrete memory centers within the brain as well as a non-localized dimension of memory functioning (Boyd, 1988)

It has been reported for children and adolescents who receive a closed head injury that memory deficits are among the most significant and pervasive cognitive problems (Dalby & Obrzut, 1991; Telzrow, 1987). Minimal head injuries classified as minor have been found to affect memory and related attentional processes. In a study which looked at measures of neurobehavioral functioning of children who received a minor head injury, researchers found

deficits in memory and attention were often more severe than other cognitive processes deficits (Levin, Mattis, Ronald, Eisenberg, Marshall, Tabbaddor, High & Frankowski, 1987).

Head injury has also been found to affect different types of memory (i.e., visual vs. verbal). Donders (1993) looked at severity of brain trauma in relation to ability to visually or verbally remember material. When general level of verbal recall was measured, no significant differences were found between groups (mild/moderate vs. severe brain insult). Results suggested a trend for the mild/moderate group to have better recall of visual information than children with severe injuries, however this trend did not reach statistical significance. Therefore, no significant differences were found between severity of brain insult and recall of either verbal or visual material. However, when measuring the ability to remember after a 45-minute delay, recall of verbally presented information deteriorated significantly regardless of injury severity. Donders (1993) suggested the delay effect occurred regardless of severity of injury because memory encoding or storage processes for verbal information may be extremely sensitive to any degree of brain damage, even mild levels. No such deterioration was found for recall of visually presented information. The author concluded since the poorer performance of the severe group on the immediate recall trial was almost a standard deviation below the mean initially, there was relatively less to be forgotten on the delayed recall which resulted in the loss being non-significant for the delay trial.

There appears to be clear support for the conclusions that the temporal lobes are vital in episodic memory and that right and left sides are functionally differentiated according to the

verbal or nonverbal nature of the task (Paivio & te Linde, 1982). For example, hemispheric differences in memory deficits have been documented. Left-sided lesions appear to be more important in remembering verbal information, while right-sided lesions tend to especially impair memory of visual and spatial information (Kolb & Whishaw, 1987). This is consistent with current neuropsychological theories of brain organization, which discriminate between left and right hemispheric function (Halstead, 1947; Luria, 1973).

Tasks that rely on verbal processing are believed to reflect left brain functioning. Visual tasks are believed to be indicative of right hemisphere functioning. Following this verbal vs. visual differentiation between separate hemispheric functions, designs of the newer memory tests, including the WRAML, have included measurement of both types of abilities.

Gifted and Memory

Increased and/or enhanced memory performance has been linked with high ability students (Dark & Benbow, 1991) and good memory skills have been found to be indicative of giftedness at the preschool level (Guilford, Scheuerie, & Shonburn, 1981). While enhanced memory is one characteristic often attributed to gifted children, Lovecky (1994) makes the distinction between moderately gifted and exceptionally gifted. She describes the “prodigious memory capacity” which many associate with being gifted as characteristic of only the exceptionally gifted (e.g., those with IQ’s near 200) (p. 119).

While some studies purport gifted children are highly efficient in their use of both short- and long-term memory, Jackson and Butterfield (1986) point out that based on the available data, a firm conclusion that the gifted can be distinguished by the efficiency of their memory processes cannot be drawn. They suggest better memory performance may be an indication of a faster rate of responding or that the gifted child has greater familiarity with the letter or number stimuli used. They also criticize the data because it fails to address the issue of whether the enhanced memory of gifted children is generalized to all types of information or specific to certain fields.

It has been proposed that gifted children have more knowledge about memory (metamemory) than normal children (Sternberg, 1981). A child who has a mature metamemory is described as one who has a variety of study skills and useful techniques for retrieving long-term memories as well as an ability to monitor the success or failure of an on-going learning activity (Carr & Borkowski, 1987). Research with talented children has found one of the most reliable differences between the cognitive behaviors of gifted and average children is their use of strategies on memory and problem solving tasks (Jackson & Butterfield, 1986; Siegler & Kotovsky, 1986). Strength of memory strategies have been found to predict performance on memory tasks for both gifted as well as average children (Kurtz & Weinert, 1989). Overall, the majority of the research supports the idea that gifted and talented children have significantly higher metamemory skills than non-gifted children (Cheng, 1993; Jackson & Butterfield, 1986;

Rogers, 1986; Siegler & Kotovsky, 1986; Sternberg, 1981), however a few have failed to find such a difference (Kontos, Swanson & Frazer; 1984)

Research has found that memory skills are correlated more with those who are gifted mathematically vs. those verbally gifted. Using the coding subtest of the WISC-R, Benbow and Minor (1990) found enhanced memory to be more strongly associated with mathematical talent than with verbal talent. Further analysis utilizing a variety of digit and spatial tasks to test for aspects of working memory found similar outcomes (Dark & Benbow, 1990). Results suggested the mathematically talented group had a superior skill manipulating information in central working memory (i.e., short-term memory).

Dark and Benbow (1991) furthered their investigation by looking at differences in encoding information, differences in manipulating information, and differences in storing information in long-term memory between verbally and mathematically talented youth. Results reported the ability to manipulate information in working memory to be related to mathematical talent as they had previously found. Verbally talented youth were found to be much better at enhanced retrieval (i.e., encoding) of information from long-term memory into working memory. However, working-memory representational capacity was found to vary differentially between ability groups as a function of the type of stimulus. Gifted math students were found to excel at digit stimuli, whereas verbal precocious youth were found to be better at word stimuli. The authors suggest this is due more to representational differences in long-term memory than to differences in working-memory operations. These authors point out that earlier studies relating

intellectual ability to enhanced memory function did not always separate verbal and mathematical ability and that the tasks measured reflected primarily speed of encoding. They suggest that enhanced working-memory operations are more strongly associated with math abilities and that speed of encoding is more strongly associated with verbal skills.

Research has also begun to investigate the differences between learning disabled gifted children and non-learning disabled gifted children. Memory deficits in learning disabled gifted children have been found (Kitzen, 1983; Maker, 1982). Waldron and Saphire (1992) looked at the perceptual and memory characteristics of learning-disabled gifted students as compared to regular gifted youth. Results found the gifted who were learning disabled were significantly weaker in their short-term auditory memory skills. However, differences between groups were not found in visual memory. The authors suggested the students' comparative strengths in visual memory may indicate their reliance on memory for "sight words", i.e., those encountered frequently or not analyzed by phonics. Steeves (as cited by Kitzen, 1983) found that when compared to average non-dyslexic students, mathematically gifted dyslexics scored significantly lower on memory tests.

Hoffman (as cited by Geffen, 1989) compared memory abilities of gifted children who had high reading achievement to those with low reading achievement. Those with low reading achievement were found to have deficits for sequential auditory memory, which is similar to regular children who are learning or reading disabled.

Marx (1992) completed a study looking at susceptibilities to inferential bias in memory in regular and gifted classes in 2nd, 4th, and 6th grades. Short stories were read to each class and then verbatim and inferential test items were presented which were to be marked true or false. This study investigated forward-consequence inferences which meant that marking a statement as true was assumed to indicate the acceptance of a plausible but not logically required inference (i.e., implies that some particular event had occurred, although it had not specifically been described). Results found that susceptibility to inferential bias in memory showed no improvement over grades for the regular students. For the gifted students, improvement was evidenced only in the 6th grade. For verbatim items, both gifted and regular students showed the expected improvement over grades, as well as the expected superior performance of the gifted students. This study suggests susceptibility to inferential bias in memory is developmental and it appears that gifted show an advantage over those of normal intelligence.

Geary and Brown (1991) assessed strategy choice and information processing differences in gifted, normal, and mathematically disabled 3rd and 4th grade students. Long-term memory was suggested to be the primary factor behind the observed group differences on the mathematics achievement test and the developmental maturity of the strategy mix. This factor was described as a nearly adult-like long-term memory organization of basic math facts, although the rate of fact retrieval was relatively slow compared to that of adults found in previous research (Miller, Perimutter, & Keating, 1984).

Gaultney, Bjorklund, and Goldstein (1996) looked at whether or not strategic processes were more developed in gifted than in non-gifted in a series of memory experiments. In experiment 1, results suggested gifted youth were no more likely to benefit from the use of a memory strategy than non-gifted children. The gifted children were found to perform significantly better than the non-gifted when a strategy was not employed. However in experiment 2, they found strategy use was more likely to be helpful to the gifted when it was less costly in terms of cognitive capacity. The authors suggested the gifted were able to immediately recognize the benefit of using the strategy indicating superior metamemory skills for these children. In the final experiment, nonsense words were used in the memory task. Results found that gifted youth utilized more active strategies than the non-gifted group. Overall, the data obtained suggest, that strategic processes as well as the knowledge of when best to use such strategies, are what most benefits task performance and that the gifted are better at this than the non-gifted. Results also suggest that the gifted youth's strategy use is task-dependent and that some portion of their high level of memory is the result of superior nonstrategic functioning.

Saccuzzo, Johnson, and Guertin (1994) looked at ethnic differences on four measures of information processing in gifted versus nongifted children. One-half the children were in 2nd to 3rd grade and the other half were in 5th to 6th grade. There was an equal number of children from four ethnic backgrounds: African American, Latino, Filipino, and White (10 gifted, 10 nongifted). The four tasks consisted of inspection time (backward masking paradigm), reaction time, coincidence timing, and mental counters (working memory). The "memory" task required

subjects to simultaneously hold, revise, and store three counter values that changed rapidly.

Gifted students were found to do significantly better on all four tasks. Their superior performance was found to be independent of ethnic background.

Looking at brain hemisphere differences, Benbow (1988a) hypothesized the usual performance asymmetries found on various laterality tasks might be lessened or perhaps reversed in a gifted population. O'Boyle and Benbow (1990) investigated this possibility by looking at gifted vs. non-gifted (average) performance on a dichotic listening task and a free-union chimeric face task. On the dichotic listening task, the average students displayed the usual right ear/left hemisphere advantage, which reflects the specialized capacity of the left hemisphere for linguistic processing. The gifted students, however, were equally accurate with either ear, which suggests that in the gifted brain the right hemisphere was more involved during linguistic information processing than previously thought. As far as the chimeric face portion, both groups showed a right hemisphere bias, although the gifted were significantly more likely to choose the left side smile/right side face which is indicative of enhanced right hemisphere involvement in the task. This right hemisphere bias was found to be correlated with gifted SAT performance, i.e., higher SAT scores were positively related to greater involvement of the right hemisphere. The authors point out that in a related EEG study (O'Boyle, Alexander, & Benbow, 1991), during chimeric face processing, gifted males exhibited alpha-wave suppression localized to the right temporal lobe which indicates cortical activation in this region. The lack of such lateralized EEG

activity in average ability subjects adds support to the idea of enhanced right hemisphere involvement in the gifted.

Further investigation into enhanced right hemisphere involvement looked at concurrent finger-tapping with a verbal task in a mathematically gifted male group vs. average ability group (O'Boyle, Gill, Benbow, & Alexander, 1994). Evidence was found to support previous findings (O'Boyle et al., 1991; O'Boyle & Benbow, 1990). O'Boyle et al., (1994) found that not only did gifted individuals tap faster, their tapping rate was reduced for both the right and left hands relative to baseline when they were engaged in the concurrent verbal task. The average ability students, however, only showed a right-hand reduction in tapping rate. The results suggest that in the gifted brain, both left and right hemispheres share basic aspects of linguistic processing as opposed to the average ability subjects who appear to rely primary on the left hemisphere for such verbal processing tasks.

There appears to be a wide variety of research on memory with the academically talented. While this research has attempted to differentiate between auditory memory and visual memory (Waldron & Saphire, 1992), no attempt has been made to differentiate between verbal memory and visual memory with these youth

The Wide Range Assessment of Memory and Learning (WRAML)

The WRAML was developed to fill a void in well-standardized psychometric assessment of memory in children. According to the authors, it was designed to be consistent with current theoretical models of memory and with current neuropsychological findings on

memory (Sheslow & Adams, 1990). According to Mealer (1994), this instrument represents the first comprehensive, well-structured scale that measures a youth's ability to actively learn and memorize a variety of information. The test is purported to be sensitive to developmental changes in memory and learning functions and has included educationally relevant tasks (Sheslow & Adams, 1990). Subtest selection criteria included the requirement that tasks reflect everyday functioning. Specifically the subtests were constructed:

- 1) to allow assessment of modality specific competencies (i.e., visual vs. verbal deficits);
- 2) to vary along the episodic-semantic continuum so that subtests require the memory of discrete, nonmeaningful bits of information, while others are tasks of a meaningful nature;
- 3) so that some learning could be assessed through a multiple trials procedure to allow the evaluation of a child's memory strategies;
- 4) to allow the assessment of varied criterion performances (immediate vs. delayed recall vs. recognition);
- 5) to allow for the evaluation of memory function across childhood and adolescence (Sheslow & Adams, 1990; pp. 6-7).

Essentially, the WRAML was developed to provide clinicians with a tool to measure memory function in "normal" school-aged children in a meaningful multidimensional integrated fashion. There are three major divisions within this test (Sheslow & Adams, 1990). The first

attempts to distinguish between memory and learning. Each learning subtest is administered across four trials in an effort to measure acquisition of new material. The memory subtests provide a discrete amount of information to be remembered as well as requiring immediate recall. The authors caution that no conceptual distinction between memory and learning is intended, rather this distinction allows for different aspects of the memory processes to be evaluated (Sheslow & Adams, 1990).

The second division differentiates between visual and verbal abilities. Subtests within each modality progress from rote memory of less meaningful items to memorization of increasingly meaningful material. The third distinction is made between short-term (within seconds) and delayed recall (20 to 40 minutes). The delay recall allows one to assess the loss of information over time, i.e., forgetting.

Four composite measures are obtained from the nine subtests. See Appendix A for description of each subtest. The composite measures are: the Verbal Memory Index (VERI), the Visual Memory Index (VISI), the Learning Index (LRNI), and the General Memory Index (GMI).

1) The Verbal Memory Index (VERI) is a measure of verbal memory abilities and is considered to be analogous to left brain functioning. This scale allows one to assess rote memory capabilities and to compare them with tasks that increase in semantic complexity. Sheslow and Adams (1990) feels this allows one to form hypotheses about the child's ability to

utilize language (semantics) as an aide or detractor in remembering. This index is composed of three subtests: number/letter memory, sentence memory, and story memory.

2) The Visual Memory Index (VISI) is a measure of visual memory skills and is speculated to be analogous to right brain functioning. These are constructed along a dimension of increasing meaningfulness as well and allow one to evaluate if the increase in meaning affects memory abilities. It is composed of three subtests: finger windows, design memory, and picture memory.

3) The Learning Index (LRNI) consists of one verbal, one visual, and one cross-modal task. This index is a measure of acquired memory over repeated trials. Each learning subtest is administered across four trials in an effort to measure acquisition of new material. Three subtests composed this index: verbal learning, visual learning, and sound symbol.

4) The General Memory Index (GMI) is a composite of all the scales (VERI, VISI, & LRNI). It is purported to be a measure of overall memory ability.

The delay recall tasks provide an indication of whether information was retained in long-term storage. While information in the sensory register may be adequate for performance on the initial subtest, time and additional task requirements between presentation and delayed recall requires processing into the long-term store. This instrument allows for an evaluation of levels of processing due to the subtests increasingly meaningful content within each index. Some children may be more able to remember meaningful information, which requires further processing, than

less meaningful material. This instrument also allows one to look at the differences in verbal vs. visual performance and how each domain of performance contributes to overall memory ability.

Factor analysis research. The WRAML authors applied a principal components factor analysis to their normative data and produced a three factor solution: Verbal Memory, Visual Memory, and Learning. However, the division between learning and memory constructs appears not to be as distinct as originally hypothesized. For example, the authors acknowledge the visual learning subtest is associated more strongly with the VISI vs. LRNI, while the story memory subtest loads more strongly on the LRNI than on VERI (Sheslow & Adams, 1990; Whitaker, 1993).

While support for the original factor structure has been found using multiple regression analysis (Wheaton, 1994), other investigations have found the subtests contained more unique rather than common variance suggesting that the subtests are not highly associated and tend to stand alone (Gioia, 1998; Callahan, Haut, Haut, & Franzen, 1993). Several studies using factor analysis have produced a three factor structure, although a factor solution different than that of the WRAML authors (Aylward, Gioia, Verhulst, & Bell, 1995; Burton, Donders, & Mittenberg, 1996; Gioia, 1998; Phelps, 1995; Wasserman & Cambias, 1992). See Table 2 for a summary of results of these studies.

Wheaton (1994) administered the WRAML with 62 normal junior high students (6th - 8th). She employed a multiple regression analysis and found the regression equation between the WRAML index scores strongly predicted the GMI. This equation was statistically significant

and accounted for 99% of the variance. Specifically, she found significant correlations between the Index scores and the GMI, which provided evidence to support the factor structure of the WRAML as purported by Sheslow and Adams (1990).

Table 2

Summarization of WRAML Factor Studies

Author/population	Factor 1	Factor 2	Factor 3
Sheslow & Adams, 1990 original factor finger windows	<u>Visual Memory</u> picture memory design memory number/letter	<u>Verbal Memory</u> story memory sentence memory visual learning	<u>Learning</u> verbal learning sound symbol structure
Wasserman & Cambias, 1992 standardization 5-8 data	<u>Visual Memory</u> picture memory design memory finger windows visual learning	<u>Verbally-Mediated Memory</u> verbal learning story memory sound symbol number/letter (sentence memory) (visual learning)	<u>Attention/Immediate Recall</u> finger windows sentence memory
9 -17 yrs	picture memory design memory finger windows visual learning	verbal learning story memory sound symbol (sentence memory) (visual learning)	finger windows sentence memory number/letter
Gioia, 1998 5-8 yrs standardization data	<u>Visual/Verbal Learning</u> picture memory design memory finger windows verbal learning story memory sound symbol	<u>Visual Learning/Memory</u> design memory number/letter visual learning	<u>Verbal Span</u> sentence memory

9-17 yrs	<u>Learning/Memory</u> picture memory design memory verbal learning finger windows sound symbol visual learning	<u>Verbal Learning/Memory</u> verbal learning story memory	<u>Verbal Span</u> sentence memory number/letter
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Table 2 Continued

Author/population	Factor 1	Factor 2	Factor 3
	<u>Visual Memory</u>	<u>Verbal Memory</u>	<u>Attention/Concentration</u>
Burton et al., 1996 standardization design data 5-8 yrs & 9-17 yrs	finger windows memory verbal learning picture memory visual learning	story memory sentence memory sound symbol	number/letter finger windows
Phelps, 1995 academic and learning difficulties	<u>Visual Memory</u> picture memory finger windows sound symbol visual learning	<u>Verbal Memory</u> story memory verbal learning	<u>Attention/Concentration</u> sentence memory number/letter design memory
	<u>Visual Content</u>	<u>Verbal/Semantic/ Strategic</u>	<u>Short-Term Verbal</u>
Aylward et al., 1995 attentional deficits	picture memory design memory finger windows visual learning	verbal learning story memory	sentence memory number/letter
Haut, Haut, Callahan & Franzen 1992 closed head injury, brain tumors, subst. abuse, psychiatric	<u>Visual Memory</u> picture memory design memory finger windows visual learning sound symbol	<u>Verbal Memory</u> sentence memory number/letter story memory	

	<u>Visual Memory</u>	<u>Verbal Memory</u>	<u>Attention/Concentration</u>
Burton et al., 1999	finger windows	story memory	number/letter
Learning disabled	design memory	verbal learning	sentence memory
ADHD, head injury,	picture memory	sound symbol	finger windows
Behavioral/emotional Problems	visual learning		

In contrast, three studies have reanalyzed the intercorrelation matrices published in the WRAML manual via various factor analysis procedures and have arrived at different factor solutions. None were consistent with the factor structure, which was originally found.

Wasserman and Cambias (1992) re-analyzed the standardization data utilizing a principal components analysis followed by varimax rotation (version 4 of SPSS-X). The researchers identified the same three factors solution for each age group (5-8; 9-17), however the factor structure was different from the original one found. They found a Visual Memory factor, a Verbally- Mediated Memory factor, and an Attention/Immediate Recall factor. However, the subtests which loaded on each respective factor differed by age group (see table 2).

Wasserman and Cambias (1992) suggest the age-related factorial composition changes reflect the probability that specific tasks are mediated by different cortical mechanisms at different ages.

Gioia (1998) re-examined the data using a principal factor analysis (PFA) as opposed to the principal components analysis (PCA) which was used by the WRAML authors. This was based on rationale proposed by Carroll (1988, as cited by Gioia, 1998) and Snook and Gorsuch (1989, as cited by Gioia, 1998) which supports use of PFA because the common

variance between the subtests was the critical element being analyzed, excluding the subtests specific factor variance. Therefore, PFA was felt to provide a more parsimonious view of the relationship between subtests and the underlying factor structure than would PCA. A three factor solution was found, however, the solution was different than the original and it differed slightly between the age groups. The three factor solution for the 5-8 year olds was defined by a mixed Visual/Verbal Learning and Memory factor, Verbal Span factor, and a Visual Learning and Memory factor. The PFA solution for the 9-17 year old group included a general Learning and Memory factor, a Verbal Span factor, and a Verbal Learning and Memory factor. Further analysis of a two or four factor solution did not increase interpretability.

Burton et al., (1996) examined the construct validity of the WRAML indexes using structural equation analysis with the standardization data. Nine latent variable models were assessed for goodness of fit across the two age subdivisions of the WRAML standardization sample. Their confirmatory factory analysis produced a three factor solution consisting of a Verbal factor, Visual factor, and an Attention factor which best fit the data. Wasserman and Cambias (1992) also obtained a similar factor structure. However, with the older age group two additional subtests were found to load high enough on the verbal factor (loading factor > .40) which according to the authors can be considered statistically interpretable.

Neither the original index score structure nor subtest placement within the three scales was supported by the re-analysis of the normative data by either group of researchers. In fact, in two studies, not one subtest was found to even be related to the Learning Index (Burton et

al., 1996; Wasserman & Cambias, 1992). The three subtests in particular (verbal learning, sound symbol, and visual learning) were found to load heavily on respective modality factors, i.e., Verbally-Mediated Memory or Visual Memory. Only Gioia's (1998) analysis found subtests to be related to learning, however, the authors concluded that the three factors that emerged were difficult to interpret given the blending of learning with memory subtests and visual with verbal subtests.

Callahan et al., (1993) also attempted to do a confirmatory factor analysis on the WRAML. However, their data included the original correlation matrix from the WRAML manual as well as data obtained from a clinical sample of 129 referrals for neuropsychological evaluation. Out of six models tested, none of the models provided adequate fit to the data. Although described as a "poor" fit, the null model (each subtest served as a single factor) was found to best fit the data, which indicated there was still a significant amount of variance within the subtests, which remained to be explained. The authors suggest the WRAML subtests should be interpreted as independent measures than as components of the indexes. The addition of a clinical sample to the standardization data may account for her results differing from others research groups who reanalyzed the same data.

Studies utilizing WRAML scores obtained from various clinical groups of children have also produced a different factor structure than the original. For example, Phelps (1995) investigated the WRAML performance of children who were experiencing academic and learning difficulties. The factor structure was analyzed by a principal components factor analysis

followed by varimax rotation (via SPSS). With this clinical sample, she found an Attention/Concentration factor, a Visual Memory factor, and a Verbal Memory factor. While her three factors were similar to Burton et al, (1996) and Wasserman and Cambias (1992), two subtests (sound symbol and design memory) loaded on different factors. The different loadings of these two subtests may be related to her sample, i.e., children with identified academic and/or learning problems.

Aylward et al. (1995) used a clinical sample of children referred for problems in school performance. The majority of these children had attentional deficits (72%), whereas 8% to 35% had learning disabilities. Researchers used a pairwise principal factor analysis with the Montanelli and Humphreys criterion. The new factor solution was comprised of Visual Content, a Short-Term Verbal, and a Verbal/Semantic/ Strategic factor (see Table 2). Sound symbol was found not to load significantly on any factor. Authors recommended modality-related (strategic/ nonstrategic) and functional processing dimensions (episodic/semantic) be used in a clinical setting in the evaluation of children's memory.

Haut, Haut, Callahan and Franzen (1992) investigated the factor structure of the WRAML with a clinical population. Subjects were a mixed clinical group and were referred for evaluation with diagnoses including closed head injury, brain tumors, substance abuse, and a variety of psychiatric diagnoses. Using principal factor analysis through SAS utilizing PROMAX oblique rotation, a verbal memory factor and a visual memory factor were found (see Table 2). Verbal learning was not found to clearly align with either the verbal or the visual memory factor.

However, authors caution the results may be a product of the specific sample used, that is, children and adolescents for whom attentional dysfunction was inherent.

Burton, Mittenberg, Gold, and Drabman, 1999 (1999) looked at a clinical sample of children referred for cognitive assessments. Diagnoses included the following: learning disability, ADHD, head injury, and behavioral/emotional problems. Ten latent variable models were evaluated for goodness of fit using LISREL VII software. Their results were identical to those obtained by Burton et al., (1996) which found identical subtest loadings on a three factor solution consisting of a Verbal factor, Visual factor, and an Attention factor. These findings were found for both age groups.

Results of the factor studies utilizing a clinical population strongly suggest that the original three scale WRAML configuration (verbal, visual, & learning indices) not be employed in clinical interpretation (Aylward et al., 1995; Burton et al. 1999, Haut et al., 1992; Phelps, 1995). Overall, the factor analysis research has produced a variety of factors solutions, none of which are identical to the original found by the authors. However, four out of the seven studies, found a factor solution for a verbal, visual, and an attention factor (Burton et al., 1996, Burton et al., 1999; Phelps, 1995; Wasserman & Cambias, 1992). Two of these three studies reanalyzed the standardization data and found identical subtest loadings on the respective factors (Burton, 1996; Wasserman & Cambias, 1992). Although at the higher age group, two additional tests were found to additional load on the verbal factor (Wasserman & Cambias, 1992). A third study included a clinical sample with the standardization data and found similar

subtest loadings on the three factors except for design memory and sound symbol, which may be accounted for by the nature of mixing a “clinical” sample with a “normal” sample.

However, if one takes a look at specific subtest loadings on respective factors across the studies, the reliability of subtest loadings seems greater than that suggested by the various factor studies. Finger windows and picture memory were found to load on a visual or visually-related factor while story memory was found to load on a verbal or verbally-related factor for all studies. Design memory and visual learning were found to load on a visually-related factor in six out of seven studies. Verbal learning was found to be related to a verbal factor in five out of the seven studies. The remaining four subtests were found divided between two factors. Number/letter and sentence memory were found in three studies to load on attention and in four studies to load on a verbally-related factor. Sound symbol was found in two studies to load on a verbal factor and in three studies on a visual factor.

What appears to differ significantly across studies is the title chosen to name the factor. For example, sentence memory and number/letter included as a factor has been called Short-Term Verbal (Aylward et al., 1995) as well as Verbal Span (Gioia, 1998) and with the addition of finger windows, the factor has been called Attention/Immediate Recall or Attention/Concentration (Burton, 1996, 1999; Wasserman & Cambias, 1992). Only Gioia's (1998) analysis found subtests to be related to learning, however the authors concluded their three factors were difficult to interpret given the blending of learning with memory subtests and visual with verbal subtests. As Tabachnick and Fidell (1989) point out, this is one of the main

criticisms against factor analysis, i.e., how one experimenter interprets and titles a factor can and will often differ from that of another researcher even though they may be looking at the same data and subtests.

Attention. Other studies also suggest that attention plays a role with the WRAML. Haut, Haut, and Franzen (1992) investigated the relationship between attentional factors and WRAML subtests. They found that two subtests (number/letter memory and finger windows) via correlational analysis were more closely associated with attentional factors than with verbal or visual memory. Furthermore, their results indicated this relationship could not be explained by deficits in general cognitive processing. These authors suggest attention may play a much greater role in memory processes of children than in adults.

Adams, Sheslow, Robins, and Wilkinson (1992) in a study with children with attention-deficit/ hyperactivity-disorder found performance on number/letter memory and finger windows to be significantly worse than normal controls. This suggests that children from populations with a high prevalence of attentional deficits (i.e., ADHD) may have particular difficulty on subtests that involve episodic/non-strategic (rote) processing of verbal information because of a higher attentional load (Aylward et al., 1995, Adams et al., 1991).

Overall research investigating children with ADHD has produced mixed results. Two studies have shown that ADHD youth are distinguishable by their scores on the WRAML (Mealer, 1994; Adams et al., 1992), while Phelps (1995) found this instrument to show an inability to distinguish between groups.

Mealer (1994) looked at the utility of the WRAML in discriminating between children (ADHD, clinic-referred, and non-clinic referred) who had ADHD diagnoses from those who did not. She found that children with ADHD were more likely to have lower scores on the LRNI and the VISI than children who had other diagnoses or no diagnosis. She also found children with ADHD scored lower on the subtests of verbal learning and finger windows. These subtests measure immediate recall which suggest that children with ADHD do not have trouble with storage of information, but with the initial processing (Mealer, 1994).

Adams et al., (1992) investigated the differences in memory between 25 children with ADHD and 50 matched normal children in a control group. There was no comorbidity of learning disabilities with any child in the ADHD group. The ADHD group achieved significantly lower scores on the GMI, VERI, and VISI. The authors concluded that the significant differences seen between the GMI, VERI, and the VISI resulted from weaknesses in rote memory ability for the ADHD group. They did note as the task increased in meaningfulness and decreased in random presentation, differences between the ADHD and control groups faded. This is similar to results found with arithmetic disabled children and the WRAML. As a total group, arithmetic disabled subjects achieved better scores on tests with more meaningful stimuli than on those with less meaningful stimuli (Pennett, 1994).

Phelps (1995) used the WRAML in an attempt to distinguish between children with attention deficit/hyperactivity disorder, those who were learning disabled, and a control group of non-ADHD or non-LD children. Using a discriminant function analysis, she found that the

WRAML provided little distinguishing information between these groups. She found that the neither the VERI, VISI or the LRNI showed any statistically significant deficits with either the children with ADHD or those with learning disabilities. Performance was similar across all three groups.

Other WRAML Research. Haut, Williams, and Hendon (1994) used the WRAML with children and adolescents who had conditions affecting neuropsychological functioning (epilepsy, traumatic brain injury, and substance abuse) as compared to a nonneurological psychiatric disturbance group. Results found children with epilepsy scoring significantly below subjects with substance abuse or psychiatric controls on the VERI. Children with epilepsy also demonstrated more variability on both verbal and visual memory tasks as compared to other groups. All groups had difficulty with number/letter memory, which is purported to be a measure of auditory attentional skill which suggests auditory attentional skills have a significant impact on memory performance in this child clinical group.

Haut, Robyn, Haut, and Kirk (1995) looked at memory functioning in adolescents with schizophrenia and those with ADHD as compared to a normal matched group. On the GMI and VISI, the group with schizophrenia performed more poorly than the group with ADHD who performed more poorly than the control group. On the LRNI, the schizophrenia and ADHD group performed more poorly than the normal group. Specifically on picture memory, patients with schizophrenia performed more poorly than the patients with ADHD who performed more poorly than controls. When evaluating delayed recall scores, on delayed recall

of story memory, those with schizophrenia were found to perform more poorly than the controls. Results indicate memory deficits appeared more prevalent when examining memory index scores, yet when subtests were examined individually, the support was not as strong. These results add to the concern regarding interpreting the WRAML at the index level.

Achievement Research

Research has also been done looking at memory and achievement. Developmental differences in memory and achievement have been demonstrated by the authors of the WRAML (Sheslow & Adams, 1990). An interaction effect was found to exist between age and the relationship between type of memory and achievement area. Children aged 8-11 and 16-17 years old were administered the WRAT-R and the WRAML. The GMI was significantly positively correlated with reading, arithmetic, and spelling in the 8-11 age group. Also, in this younger group, the three areas of achievement were significantly related to the VERI and LRNI. The VISI was found to only be related to reading. In contrast, the GMI and the LRNI were significantly positively correlated with arithmetic achievement only in the 16-17 year old group. VERI correlated with all three areas of achievement in this older group, while VISI correlated with none. These data suggest that various aspects of memory are differentially related to academic achievement at distinct ages (Sheslow & Adams, 1990).

Reading Achievement. Hainlen (1994) investigated the WRAML in relation to math and reading achievement scores earned on the Woodcock-Johnson Revised Test of Achievement. She found the VISI and VERI to be predictive of broad reading. Previous research with

younger children (8-11 yrs), however, had found that the VISI was significantly related to reading, while only VERI was significantly related to achievement in reading for older children (16-17 yrs) (Sheslow & Adams, 1990). Hainlen's (1994) work suggests that her age group of children, age 11-14 years, were in the process of changing their mental strategies from predominantly visual to predominantly verbal.

Hainlen (1994) also found that the LRNI was not a significant predictor of reading achievement. Sheslow and Adams (1990) on the other hand had found that the LRNI was significantly related to reading achievement for the younger children, but not for the older adolescents. The LRNI subtests are all based on four repetitious memory trials. This indicates that younger children use different information processing skills as opposed to adolescents. Once children become older they are able to process semantic information at a deeper level (Hainlen, 1994).

Math Achievement. Sheslow and Adams (1990) had found that the VERI as well as the LRNI to be related to arithmetic achievement. However, Hainlen (1994) found that only the VERI was significantly predictive of the broad math score on the Woodcock Johnson. Hainlen's results suggest her sample of 11-14 year olds appeared to rely heavily on verbal memory or verbal mediation strategies. Additional analysis of the two subtests, which comprise broad math on the Woodcock Johnson, found that both VERI and LRNI were significant predictors of Calculation requiring formal math operations. Only the VERI was a significant predictor of the Applied Problems subtests which does not require utilization of rote memory

strategies, such as those required for formal math operations and found in the Learning Memory Index. As Hainlen's group were older, results suggest that children rely more on verbal mediation strategies in math related problems.

In summary, the WRAML has been able to show developmental trends in reading and math achievement. The above cited research has shown, in relation to reading skills, that children change their mental strategies from visual to verbal as they age. This is consistent with developmental memory research, which shows a gradual reduction in the dominance of visual memory as a child ages (Schneider & Pressley, 1989). This research also suggests children use different information processing skills at different ages. In relation to math skills, the research indicates that as children age, they rely less on verbal mediation strategies and tend to use other strategies as well.

Mechanical Reasoning and Spatial Abilities

The concept that intellectual abilities are arranged along three primary content domains (verbal-linguistic, mathematical-numerical, and spatial-mechanical) is a growing concurrence among leading psychometricians (Ackerman, 1989; Humphreys, 1979; Snow & Lohman, 1989). Although spatial ability has been recognized as a distinct and separate dimension of human intelligence for approximately a half of a century, this ability has never received the scrutiny that verbal and mathematical reasoning have (Kovac, 1989).

Humphreys, Lubinski, and Yao (1993) believe spatial abilities are extremely important for educational-vocational paths such as engineering, architecture, and physical sciences as well as many of the creative arts. These authors suggest these disciplines are losing many talented persons by restricting assessment to conventional mathematical and verbal abilities such as the SAT. Others as well argue that mechanical comprehension and spatial ability measures could be utilized in selection processes to tap heretofore untapped talent for engineering and the physical sciences (Achter et al., 1996; Lubinski, & Benbow, 1994). Evidence has been found that performance on ability tests such as mechanical reasoning are predictive of job performance (Hattrup & Schmitt, 1990). For example, spatial ability has been found to predict engineer's performance in reading line drawings (Snow & Lohman, 1989).

Spatial visualization ability has been found to be important in mechanical reasoning skills. Hegarty and Sims (1994) found that accuracy in a mechanical reasoning task was related to spatial visualization ability. Subjects with high-spatial ability were found to be successful on the mechanical reasoning task, while those with low-spatial ability had a significantly poor performance. These authors suggest that mental animation or the ability to infer motion from static diagrams is a component of mechanical reasoning and further contend mental animation is related to spatial visualization ability.

In addition to mechanical reasoning, spatial skills have also been linked to reading abilities. Crano and Johnson (1991) suggest skilled reading, in part, is facilitated by an enhancement of spatial skills. Subjects with reading deficits were randomly placed either in a

remedial reading course or a remedial reading plus map/graph instruction with material designed to enhance spatial interpretation skills. The treatment groups were then compared to a no-treatment control group on various reading abilities. Results indicated that the addition of the spatial skills training program increased the acquisition of lower level reading skills (i.e., reading speed, accuracy, and vocabulary) above that of only a remedial reading course. Their analysis suggested these lower level skills appear to be functionally related to reading comprehension.

A variety of tests have been designed to measure spatial ability. Recently a spatial test was created using the same item type as previous tests (e.g., DAT Space Relations), but designed by applying cognitive design principles. The Spatial Learning Ability Test (SLAT, Embretson, 1994) is purported to be a better measure of pure spatial ability because the impact of verbal abilities was substantially reduced due to the nature of its design. Embretson (1996) conducted a confirmatory factor analysis using the DAT-S and the SLAT and found that verbal ability was more heavily loaded in the DAT-S than on the SLAT. She conducted a residualized factor structure in which the spatial test correlations were controlled for linguistic coding. In this residualized factor structure, linguistic coding ability was partialled out of the spatial ability tests. The remaining correlation of the spatial tests with Verbal Reasoning was found to be small and the added split loadings did not improve model fit. Therefore, the author suggested linguistic coding ability was the primary aspect of verbal reasoning in spatial tests, especially that of the DAT-S.

Embretson's (1996) results support Just and Carpenter's (1985) hypothesis that spatial test items involve verbal analytic processing. The authors suggest a spatial test item may be solved by converting the visual stimuli to a linguistic code and then by applying verbal reasoning until a solution is derived. Thus, success on spatial items is due to verbal ability rather than spatial ability.

Research has begun to look at respective abilities of those gifted in mathematics vs. those verbally talented. Benbow and Minor (1990) found their group of mathematically gifted students scored higher in spatial ability and mechanical comprehension than did their verbally gifted students. These results are similar to Cohn (1977) and Dark and Benbow (1990). The latter researchers found that gifted math students were better at tasks requiring representation and manipulation of spatial information. Becker, however, (as cited in Benbow & Minor, 1990) found his group of mathematically gifted students' spatial ability was not correlated with item performance on the SAT-M

Traditionally a view has been held there is a difference in ability between males and females on performance of spatial ability and mechanical reasoning tasks (Bennett, Seashore & Wesman, 1990; Maccoby & Jacklin, 1974). There has been research to support gender differences in these abilities as measured by the Mechanical Reasoning and Spatial Relation subtests from the DAT, with males doing better than females (Feingold, 1995; Feingold, 1988; Stanley, Benbow, Brody, Dauber, & Lupkowski, 1992). However, an analysis of the DAT standardization data from 1947, 1962, 1972, and 1980 found that females had cut in half the

performance differences observed on Mechanical Reasoning and Spatial Relation subtests (Feingold, 1988). However, some researchers have failed to find this gender bias on a spatial reasoning ability task in a gifted population (Weiner & Robinson, 1986).

In discussing previous research, Casey, Nuttall, Pezaris and Benbow (1995) point out that gender differences depend upon the type of spatial ability being measured. It has been found mental rotation ability shows the strongest gender differences favoring males. This skill is described as mentally rotating a two-dimensional representation of an object in three-dimensional space. In a study that looked at the influence of spatial ability on gender differences on SAT-M scores, mental rotation skills were found to predict math aptitude for a group of gifted females but not for gifted males (Casey et al., 1995). Males were found, however, to do better on both the mental rotation task and SAT-M score. When the researchers statistically adjusted for mental rotation, the gender difference was still evident, i.e., males favored over females.

Gallagher (1989) found gender differences as well on visual-spatial ability. However, when the time restriction was lifted and subjects were allowed to finish the task at their own pace, females were more able to perform at a level consistent with that of the boys. The author suggests the poor performance on the visual-spatial task was related to speed of response rather than a lack of ability. This is similar data obtained by Dreyden and Gallager (1989) which found improved performance during untimed tests.

There is research, however, which supports it may just be a girl's lack of familiarity with activities that develop spatial ability than it is a true deficit in spatial ability. Blatter (1983) measured spatial ability via Space Relations of the DAT before and after special instruction in spatial relations. She found that females in the experimental group showed significantly greater improvement than did the boys. These results suggest that the originally lower spatial ability can be attributed to lack of experience and training rather than to biological differences. Interesting enough, she also found the girls improved significantly more than the boys in the control group. The author suggested that reinforcement may be responsible. Studies of achievement motivation of females have found their performance is more dependent on external cues and rewards than are boys and Blatter (1993) feels that having been selected to participate in a study on spatial skills may have been reinforcing for these females.

Snow and Lowman (1989) looked at the differences among poor- medium- and high-spatial ability subjects. Those who perform poorly on spatial tests differ qualitatively from other subjects by having greater difficulty generating memories of geometric shapes that retain information about the exact configuration of elements in a figure. For medium- and high-spatial ability subjects, the differences were related to speed and accuracy, the choice of solution methods, and by store of spatial knowledge.

There appears to be more investigation in the area of spatial ability than with mechanical reasoning. This is not surprising considering it is only recently that mechanical reasoning has been theorized to play a part in intelligence (Ackerman, 1989; Humphreys, 1979; Snow &

Lohman, 1989), while spatial ability has been recognized as a distinct and separate dimension of human intelligence for the last 50 years (Kovac, 1989). There is also evidence of a significant relationship of spatial visualization ability in mechanical reasoning (Hegarty & Sims, 1994). The addition of tests to measure mechanical reasoning and spatial relations skill in studies with the gifted have already found to be helpful. Achter et al., (1996) suggest these measures can enhance ability-preference profile definition as well as help in educational-vocational self-exploration in counseling settings.

Differential Aptitude Tests (DAT).

The DAT is a multiple aptitude battery designed to measure Grades 7-12 students' ability to learn or to succeed in certain areas. The battery consists of eight subtests: Verbal Reasoning, Numerical Ability, Abstract Reasoning, Spelling, Language Use, Mechanical Reasoning, and Space Relations, however, this study is only concerned with the latter two subtests.

The fifth edition of the DAT (Bennett, Seashore, & Wesman, 1990) was extensively revised and has new items, reduced administration time, and two levels (Level 1 for Grades 7-9, Level 2 for Grades 10-12). There are also two equivalent alternative forms (C and D). The standardization sample consisted of approximately 100,000 students from 520 school districts. Both separate-sex and combined-sex norms are provided in the norms booklet. Converted norm-referenced scores are reported in percentile ranks, stanines, and scaled scores. The latter is a new feature and has two advantages: 1) the comparison of test scores across levels and

forms, and 2) the sample-free conversion of raw scores to scaled scores at a given level or form (Wang, 1995).

The reliability coefficients range from .82 to .95 and reflect the highly homogeneous domains sampled by the scales (Anastasi, 1988). Wang (1995) reports that validity data for the DAT are abundant and that most scales have moderate-to-high correlation with GPAs and achievement tests. However, Wang (1995) does criticize that a factor analysis was not done on item scores in the test development. Therefore, he feels the construct validity of the test items still need empirical justification for the underlying traits assessed.

While constructing the test, it was determined that each ability measured by the DAT should be tested separately (Bennett et al., 1990). Therefore each subtest was designed to be given independently. Subtests alone as well as in differing groups have been used extensively in psychological research.

The DAT first came out in 1947 and was revised in 1962, 1972, 1980 and 1990. It remains one of the most frequently used batteries in counseling and education today and Wang (1995) states that it's continued use is a tribute to its quality, credibility, and utility. However, one of the criticisms for the earlier versions was the lack of normative data for ethnic minorities. The problem remains in the 5th edition. Only 27% of the normative data were composed of non-white students.

Scholastic Aptitude Test (SAT)

The SAT is given on a routine basis to high school seniors. It is used as an indicator of developed aptitude or achievement by most American colleges and universities (Brounstein & Holahan, 1987). Specifically, the math and verbal scores have been predictive of success in college. Willingham, Rock, and Pollack (1991) found these scores add significantly to the prediction of first year college grades even after the effects of high school rank and grade-point averages have been taken into account. He also found these scores are related to overall scholarship, nominations for being most successful, and receipt of college and departmental honors upon graduation. Brounstein and Holahan (1987) looked at the pattern of change in scholastic abilities as measured by the SAT among academically talented adolescents (12-16 yrs) during a three to four year period. Sixty-six percent of students who had an initial area of weakness showed substantially higher SAT score increases in their area of weakness as compared to the area of initial strength. However while the scores became more balanced between verbal and math, students kept the higher score in their initial area of strength. They also maintained their rank ordering among their peers over repeated test administrations. This data indicates SAT scores can be used to show skill improvement as well as its' reliability over repeated administrations.

A considerable amount of research in this area has been on the effects of gender on SAT performance. Sex differences do not typically show on the verbal portion of the SAT (SAT-V), however, sex differences favoring males on the math section (SAT-M) of gifted and

talented preadolescents is consistently found (Benbow, 1988b). The sex difference appears to be most pronounced at the highest levels of math reasoning ability and is stable over time.

In a review of the literature that looked at gender differences on the SAT-V, there appears to have been a change in female performance historically (Dreyden & Gallagher, 1989). In the 1960's, females were found to consistently score higher than males. By the early 70's, however, this trend disappeared and male and female performance on the SAT-V had become equivalent. Current literature shows a consistent pattern of males scoring better than females on the SAT-V, however this is only by an average of 10-12 points and tends not to be statistically significant (Benbow, 1988b).

Benbow (1988b) proposes this difference in math ability between male and female gifted preadolescents results from both environmental and biological factors. While there is agreement that males do better in math than females on the SAT, there is no agreement as to why. Explanations such as situationally induced math anxiety (Borkowski, 1990); behavioral genetics (Bouchard & Segal, 1990; Boomsma, 1990; Thomas, 1993); developmental sexual differences (Peterson, Crockett & Graber, 1990); and likeliness to volunteer (Hoyenga, 1990) have been offered in response to Benbow's (1988c) proposition of an environmental/biological interaction.

Research has found the following characteristics to be associated with high mathematical ability: spatial ability, field independence, use of images, logic, intuition, flexibility, the ability to recognize unproductive strategies, excellent memory, and high verbal and reasoning skills

(Benbow, 1988b). Later research suggests the following characteristics to be important as well:

(1) a superior ability to represent and manipulate information in short-term memory, and (2) a superior ability to translate linguistically presented math information into a mathematically useful format (Dark & Benbow, 1990). Dark and Benbow (1990) suggest these two abilities set mathematically talented youth apart from other talented youth and, in general, from college students.

Gallagher (1989) investigated predictors of SAT mathematics scores of gifted adolescents. Among the variables considered were visual-spatial ability, cognitive reasoning ability, personality type, and SAT-verbal scores. She found that cognitive reasoning ability as measured by Advanced Progressive Matrices accounted for most of the variance in both male and female regression formulas. She suggested that these cognitive skills were among the most important elements in math problem-solving. While gender differences were found on the visual-spatial task, she attributed the difference to speed of response rather than deficits in spatial ability.

Weiner and Robinson (1986) looked at gender differences, cognitive abilities, and personality in predicting math achievement of academically talented adolescents. Their results indicated that males not only had higher mathematical reasoning abilities than did females, but that this ability was the single best predictor of the male's mathematical achievement. Verbal ability was the major predictor of mathematical achievement for girls, although its predictive power was much smaller than the power of math reasoning ability for boys. Personality as

measured by the California Personality Inventory (CPI) was found to significantly predict mathematical achievement for this sample.

Dreyden and Gallagher (1989) examined the gender gap in SAT scores by testing the effects of changing time limits and phrasing of directions on the performance of academically talented males and females. Although, no significant main effect was observed, some strong trends in the data were evidenced. While, altering the directions had no effect on subject performance, both males and females performed better during untimed testing than in timed testing. This trend showed that female scores increased more than male scores did, suggesting that females poorer performance on the SAT-M may be due, in part, to speed of response. This trend supports the idea that speed of response is related to gender differences seen on SAT-M performance found by Gallagher (1989).

Purpose

The original factor structure obtained by Sheslow and Adams (1990) has failed to be replicated by either reanalyzing the standardization data or by gathering new data. However of the studies that gathered new data, none have looked at a non-clinical population. This calls into question whether the results obtained by those studies may have been biased by the sample they used. This study attempted to replicate the original factor structure utilizing a non-clinical adolescent population. The sample in this study was obtained from a group of academically talented students. While the literature reflects mathematical talent is often associated with spatial

abilities in a gifted population, the correlation between SAT-M scores and spatial skills was investigated to see if a similar relationship existed.

Hypotheses

1. It was predicted that the data obtained from a non-clinical population would fit into the original factor structure obtained by Sheslow and Adams (1990).
2. It was predicted that SAT-M would be significantly positively correlated with spatial relations scores.

Additional Research Questions

1. Would there be any ethnic differences observed on the WRAML, mechanical reasoning test, or spatial relations test?
2. Would there be any gender differences observed on the WRAML, mechanical reasoning test, or spatial relations test?
3. What would be the predictive ability of mechanical reasoning skill, spatial relations ability, visual memory, and visual memory be as far as predicting academic success (defined as GPA)?

CHAPTER II

METHOD

Subjects

Subjects were recruited from the Texas Academy of Math and Science (TAMS).

TAMS is an educational program which attempts to meet the academic needs of academically talented adolescents. Their educational approach is implemented through a rigorous two-year math and science curriculum that provides full college credit for qualified students after their 10th grade year in high school. The residential program is located on the campus of the University of North Texas. Students take a required college level curriculum that includes calculus, biology, physics, chemistry, history, English, and political science. Approximately 200 students are admitted each year to the program. Admission is competitive and is based on SAT scores, high school GPA, school and community activities, demonstrated interest in math and science, scores on diagnostic math tests, teacher recommendations, and personal interviews.

Subjects recruited were in their first year of study at the Texas Academy of Math and Science. Age range was 15.3 to 17.8 years of age. All TAMS students meeting the age requirement were offered the opportunity to participate. Of the subjects who agreed to complete the project, 64 completed the testing. Participation in the project was voluntary and there was no penalty for those who do not participate or complete the study. Because subjects

were minors, permission was obtained from their parents. Passive consent was used, i.e., notification of participation in the study was sent to parents, if they did not wish for their youth to participate, the form was to have been signed and sent back to the researcher. Feedback on all participants' verbal and visual memory abilities was offered as incentive to participate.

Materials

Wide Range Assessment of Memory and Learning (WRAML). The WRAML is a well-standardized and comprehensive instrument designed to measure verbal and visual memory skills, as well as learning capacity when repetition is given. Norms are provided for children five through 17.11 years of age. The test has two different levels (5-8 years and 9-17 years). It was developed and standardized using a national, stratified norm model based on the 1980 U.S. Census and the Rand McNally 1988 Commercial Atlas and Marketing Guide. The model controlled for age, sex, race, region, and metropolitan/nonmetropolitan residence. Each child in the normative group was administered all items of the WRAML

The test is comprised of nine subtests that yield scaled scores with a mean of 10 and a standard deviation of three. The subtests are divided and comprise three indexes. The Visual Memory Index is comprised of Picture Memory, Design, and Finger Windows. The Verbal Memory Index is comprised of Story Memory, Sentence Memory, and Number/Letter Memory. The Learning Index is comprised of Verbal Learning, Sound Symbol, and Visual Learning. A description of each subtest is contained in Appendix A.

The three indices are then combined to produce a General Memory Index. All four of the Index scores are presented as standard scores with a mean of 100 and a standard deviation of 15. The subtests contain a common factor, memory, and all subtests are intercorrelated. Correlations are low to moderate ($r = .156$ for Design Memory and Number/Letter, and $r = .605$ for Sentence Memory and Number/Letter). A complete table of subtest correlations is in Table 9 in Appendix B.

Reliability indices calculated for the subtests include coefficient alpha, person separation, and test-retest. The median individual subtest coefficients range from .78 to .90, while the General Memory Index coefficient alpha is .96 (see Table 10, Appendix C). The Person Separation Indexes for the individual subtests range from .79 to .94. The overall results from these methods of reliability investigations are acceptable according to usual criteria (Sheslow & Adams, 1990). Due to the possibility of carry-over memory from repeated administration, the test-retest administration was separated by a minimum of 60 days. Test-retest coefficients ranged from .61 to .84. These measures of stability should be used cautiously (Sheslow & Adams, 1990).

The WRAML has been reviewed and found to be well developed with good reliability (Franzen, 1990; Boyd, 1990). Franzen (1990) notes the differentiation in level of difficulty of the tasks for older and younger children. However, these tasks are the same for both groups and do not seem to consider the developmental memory strategies that children apply at different ages. For example, younger children do not systematically use active encoding strategies, while

older children do (Kail & Hagen (1982). In this respect, this instrument does not allow for an evaluation of the manner in which memory changes qualitatively as a function of age. Franzen (1990) also notes the authors fail to discuss the possibility that children will vary in the degree to which they can benefit from multiple trial procedures due to developmental status (Boyd, 1988).

Franzen (1990) notes that while most of the subtests loaded on the factors or indices to which they had been assigned, Visual Learning was found to be the exception. This subtest loaded more highly on the Visual Memory factor than on the Learning factor. Similarly, Boyd (1990) notes that one subtest (Finger Windows) loads on Visual Memory for younger children, but also loads equally high on the Verbal and Visual Memory Indices for older children. This may be due to the increase in use of verbal strategies such as mnemonics in older children or adolescents (Kail, 1979).

Consequent factor analysis research has spurred additional criticism. Wasserman and Cambias (1992) criticize the developers of the test because they feel the original data was forced to fit a theoretical framework rather than adapting theory to the empirically derived structure of the test. They also feel the developmental sensitivity is questionable, i.e., the test does not delve into the different cognitive processes used to carry out memory tasks at different ages.

Other criticisms include the inability to evaluate memory impairments and learning problems of special populations, such as attention deficit disorders (Phelps, 1995).

Consequently, the WRAML fails to aid in diagnostic decision making or to provide valid information for educational and clinical interventions

Spatial Relation Scale. This scale is one of the eight subtests from the Differential Aptitude Tests (Bennett et al., 1990). This test is a measure of the ability to deal with concrete materials through visualization. Subjects have 25 minutes to complete the 60-item test. The tasks require a subject to choose which of four 3-dimensional geometric figures matches an unfolded, 2-dimensional stimulus figure. The test requires subjects to fold mentally the four choices and choose the folded figure that matches the target figure.

Mechanical Reasoning Scale. This scale is one of the eight subtests from the Differential Aptitude Tests (Bennett et al., 1990). Each item consists of a pictorially presented mechanical situation together with a simply worded question. By looking at the picture, the subject is to choose the correct answer for the question. Subjects have 30 minutes to complete the 70-item test.

Procedure

All students in the TAMS program are required to attend weekly seminars. A short presentation explaining the purpose of the research was presented by the experimenter to these students during the weekly seminar prior to the beginning of the Fall 1997 and Fall 1998 semesters. A sign-up sheet was passed around for all those who were interested in participating. The researcher or one of her associates contacted those who signed up. All associates were thoroughly trained on the use and administration of the WRAML. Each subject was contacted

by phone and a time scheduled to administer the tests. Valid consent from each parent was on file and a valid assent from each subject was gained prior to testing. All subjects were individually administered the WRAML and the two subtests from the DAT in a room free of noise and distractions. An opportunity for verbal feedback regarding verbal and visual memory, mechanical reasoning skill, and spatial relations abilities was provided to each subject upon completion of the project.

Data Analysis

The first hypothesis predicted the data obtained from a non-clinical population would fit into the original factor structure obtained by Sheslow and Adams (1990). To test this hypothesis, the Amos Structural Equation Modeling program from SPSS was used. This particular structural equation modeling program was chosen because it allows the researcher to draw the factor model as defined by the original researchers and then perform the statistical analysis with the new data to test its fits with the predefined factor structure.

Determination of a model fit in structural equation modeling (SEM) is not as straightforward as in other multivariate procedures. None of the SEM model fit indices have a single statistical test of significance that identifies a correct model given the sample data. The only goodness of fit measure that has an associated statistical test of significance is the χ^2 . It is considered to be the most fundamental measure of overall fit in SEM (Hair, Anderson, Tatham, & Black, 1995). A significant χ^2 value relative to the degrees of freedom indicates that the

observed data and data expected from the model differ and the model is, therefore, a poor fit for the data. A non-significant χ^2 value indicates there is no statistical difference between observed data and the expected data. Consequently, the model is a good fit for the observed data. While the χ^2 is the only statistical test of significance index used in SEM, it is sensitive to sample size. As sample size decreases, generally below 100, the χ^2 has a tendency to indicate nonsignificant probability levels even if a significant difference does exist between models (Schumacker & Lomax, 1996). This increases the chance of Type I error. Therefore, other alternative goodness of fit indices are necessary in order to gain a consensus across types of measures as to whether the data fits the proposed model. Other indices to be looked at are model fit (absolute fit measures), model comparison (incremental fit measures), and parsimony measures. All goodness of fit measures were provided by the Amos Structural Equation Modeling program.

Absolute fit measures determine the degree to which the data fit the proposed factor structure. The goodness-of-fit index (GFI) measures the amount of variance and covariance in the original correlation matrix that is predicted by the reproduced matrix. It is not adjusted for degrees of freedom and has a range from 0 (poor fit) to 1 (perfect fit). While, Hair et al., (1995) propose no absolute threshold levels for acceptability have been established for this index, Schumacker and Lomax (1996) recommend values of .90 or greater reflect a good fit.

Model comparison utilizes incremental fit measures, which assess the fit of the proposed model to a null model, generally hypothesized as a single-factor model with no measurement

error. The Tucker-Lewis Index (TLI) utilizes the χ^2 in the following formula and is scaled from 0 (no fit) to 1 (perfect fit):

$$[(\chi^2_{\text{null}}/\text{df}_{\text{null}}) - (\chi^2_{\text{proposed}}/\text{df}_{\text{proposed}})]/(\chi^2_{\text{null}}/\text{df}_{\text{null}}) - 1.$$

A value of .90 or greater is recommended (Hair et al, 1995).

The final measure of model fit assessed the parsimony of the proposed model by evaluating the fit of that model versus the number of estimated coefficients needed to achieve that level of fit (Hair et al., 1995). The basic objective was to determine if the model fit was achieved by “overfitting” the data with too many coefficients. The Akaike Information Criterion (AIC) is used to compare models with differing numbers of latent variables. This index will always be positive, but values close to zero indicate a more parsimonious model. It is calculated as $\chi^2 - 2df$ (df = degrees of freedom in the model).

Once the absolute fit, incremental fit, and parsimony of the model was assessed the measurement model was next investigated. In assessing for measurement model fit, Hair et al., (1995) recommend that each of the factor constructs be evaluated by 1) examining t values for indicator loadings for statistical significance (at or above critical value of 1.96), and 2) assessing each construct’s reliability and amount of variance extracted. The recommended threshold for reliability estimates is .50 while the recommended threshold for variance estimates is .70 (Hair et al., 1995). The following formula was used to compute a construct reliability estimate for each factor:

$$\text{sum of standardized loadings squared divided by sum of standardized loadings}$$

squared plus sum of indicator measurement error

The following formula was used to compute variance extracted estimates for each factor:

sum of squared standardized loadings divided by sum of squared standardized loadings plus sum of indicator measurement error.

When reviewing the factor analysis literature for this study, it was noted that two research groups who reanalyzed the original standardization data came up with the same factor structure (Burton et al., 1996; Wasserman & Cambias, 1991). However this new factor structure differed from that found by Sheslow and Adams (1990). Because of how the Amos SEM program works (i.e., does this data fit an already defined factor model), it was of interest to this researcher to see if the data obtained in this sample would fit the factor structure found by Burton et al., (1996) and Wasserman and Cambias (1991).

Several of the factory analysis studies call for the interpretation of the WRAML to be conducted at the subtest level because of the failure of the original factor structure to be replicated. Therefore, an additional confirmatory factory analysis was conducted to see if the data would fit a model in which all subtests loaded as separate and independent factors, i.e., the independence model (Null 1). One last analysis was conducted to see if the data would better fit a one factor model (Null 2). The same statistical procedures as described above were applied to each null model analysis.

It was of interest to this researcher to see how each model (research as well as null) compared to one another in regards to explanatory power, i.e., was the data better explained

by a one or three factor model, or perhaps having all subtests stand alone. First a comparison of one null model to the other was made. This comparison was done by subtracting Null 2's χ^2 from the Null 1's χ^2 and subtracting degrees of freedom from Null 2 from Null 1. The numbers obtained were then compared to a chi-square table to assess for statistical significance. While a significant χ^2 indicated an improvement in explanatory power of the second model, a nonsignificant χ^2 indicated no real improvement from one model to the next. A comparison was then made between the two research models as well as each research model to each null model in effort to see which model best explained the data obtained in this study.

The second hypothesis predicted that SAT-M would be significantly positively correlated with spatial relations scores. To test this hypothesis, a Pearson-R correlation matrix was constructed to examine the relationship between SAT-M scores and spatial relations ability. Exploratory analysis looked at gender and ethnicity differences on memory abilities, mechanical reasoning skills, and space relations abilities. Independent t-tests were used when analyzing for these differences. However, because mechanical reasoning scores violated the assumption of homogeneity of variance when ethnicity was analyzed, a Mann-Whitney analysis was utilized. The final exploratory analysis looked at the predictive ability of verbal and visual memory skills, spatial relations ability, and mechanical reasoning skills when predicting academic success (defined as GPA). Both a multiple regression analysis utilizing all of the listed variables as well as a simple regression analysis for each variable was utilized to determine which had better predictive ability.

CHAPTER III

RESULTS

Sixty-four students from the TAMS program participated in this study. Twenty-eight were male and 36 were female students. Subjects were from five different ethnic backgrounds: 42 were white, six were Asian, 12 were African American, one was Native American, and three were Hispanic. Descriptive statistics for scores on the WRAML, DAT subtests, GPA and SAT are shown in Table 3. Overall GPA ranged from 1.79 to 4.00 with a mean of 3.24 and a standard deviation of .56. SAT Math scores ranged from 600 to 800 while SAT Verbal scores ranged from 440 to 800. Total SAT scores ranged from 1080 to 1600 with a mean of 1281.41 and standard deviation of 104.42.

Hypothesis 1

The first hypothesis predicted the data obtained would fit into the factor structure obtained by Sheslow and Adams (1990). Using the Amos Structural Equation Modeling program from SPSS, a confirmatory factor analysis was computed using the factor structure from Sheslow and Adams (1990). The χ^2 goodness of fit measure obtained for the Sheslow and Adam's (1990) model was found not to be significant ($\chi^2 = 36.13$, $p = .089$) indicating no significant difference between the observed data and that predicted by the model. While this initially implied that the data obtained in this study fit into the Sheslow and Adam's (1990) model, structural equation modeling requires that additional

Table 3

Descriptive Statistics (N = 64)

Variables	Min.	Max.	Mean	Standard Deviation
Story Memory	5	18	11.28	2.41
Sentence Memory	5	17	12.41	2.59
Number/Letter	5	16	11.03	2.45
Picture Memory	5	15	9.81	2.29
Design Memory	5	16	11.73	2.33
Finger Windows	5	17	11.59	2.55
Verbal Learning	6	16	12.02	2.35
Sound Symbol	5	15	12.06	1.97
Visual Learning	6	17	12.06	2.29
Verbal Mem Indx	78	130	109.91	11.83
Visual Mem Indx	77	132	105.44	11.86
Learning Index	89	141	114.11	11.10
Gen Mem Index	85	137	112.66	11.46
Space Relations	38	60	51.34	6.19
Mechanical Reas	41	70	57.55	6.16
GPA	1.79	4.00	3.24	.56
SAT Math	600	800	671.56	46.06
SAT Verbal	440	800	612.50	81.67
SAT Total	1080	1600	1281.41	104.42

goodness of fit measures are assessed as well. This was particularly true in this study because of low sample size ($n = 64$). The GFI was .893, the TLI was .851, and the AIC = 74.126. Neither the absolute fit measure, the GFI, nor the incremental fit measure, the TLI, met the recommended value of .90 indicating good model fit. The AIC of 74.126 indicated the model was not parsimonious. See Table 4 for goodness-of-fit measures across all model comparisons.

Table 4

Goodness of Fit Indices

	Chi-Square	df	GFI	TLI	AIC	RMSEA
Sheslow & Adams	36.13	26	.893	.851	74.126	.079
Wasserman & Cambias/Burton	30.19	26	.907	.880	74.195	.071
Null 1	103.32*	36	.000	.000	7.288	.110
Null 2	45.71*	27	.864	.735	58.234	.210

* $p \leq .01$.

When the measurement model was assessed for the original factor structure obtained by Sheslow and Adams (1990), not all t values obtained were at or above the critical level of 1.96. Two subtests, sentence memory (1.544) and number/letter (1.564), were found to be below the critical level. All construct reliability estimates were found to be below the recommended level of .50 (Verbal Memory = .38; Visual Memory = .22; Learning = .26) characterizing the predicted factors were poor indicators of the latent construct defined by each factor. All variance estimates for this model fell below the

recommended level of .70 (Verbal Memory = .60; Visual Memory = .45; Learning = .51) indicating that more than half of the variance for each of the three factors was not accounted for by the specific construct.

As discussed in the data analysis section, further analysis investigated the factor structure obtained by two sets of researchers who reanalyzed the original standardization data (Burton et al., 1996; Wasserman & Cambias, 1991). The χ^2 goodness of fit measure was found not to be significant ($\chi^2 = 30.19$, $p = .14$), indicating no significant difference between the observed and predicted data. Once again, because of low sample size other goodness-of-fit measures were again determined. While the GFI (absolute measure fit) of .907 reached an acceptable level recommended by some (Schumacker & Lomax, 1996), others disagree. For example, Hair et al., (1995) noted this index has not been adjusted for model parsimony and therefore should be examined in conjunction with incremental fit and parsimonious fit indices to ensure acceptability of the model from other perspectives. Neither the incremental measure fit (TLI of .880) nor the parsimony fit measure (AIC of 74.195) indicated model fit.

When looking at t values for indicator loadings on this second research model, all variables except one were found to be significantly related to their specified constructs. Finger windows was found not to be significantly related to either factor it loaded on, i.e., Verbal Memory (finger window = .894) or Visual Memory (finger window = 1.895). When computing each factor's construct reliability, all reliability estimates were found to be below the recommended level of .50 (Verbal Memory = .39; Visual Memory = .24; Learning = .25). These construct reliability estimates found the proposed factors were

poor indicators of the latent constructs as was found with Sheslow and Adam's (1990) model. When computing the variance extracted estimates, all estimates fell below the recommended level of .70 (Verbal Memory = .60; Visual Memory = .55; Attention = .49) indicating that on two factors, three-fourths of the variance for each factor was not accounted for by the specific construct.

Neither three factor model was supported by the results. As previously explained, the data fit of two null models was next investigated. For the Null 1 model, the chi-square was found to be significant ($\chi^2 = 130.23$, $p = .00$) indicating the data did not fit the model. For the Null 2 model, the chi-square was also found to be significant ($\chi^2 = 45.71$, $p = .01$) indicating the data did not fit this model either. Both models had extremely poor goodness of fitness measures, however the Null 2 model fit the data substantially better than the Null 1 model (see Table 4).

Comparison of explanatory power of one model over the next was conducted. A significance difference between both null models when comparing chi-square and degrees of freedom ($\chi^2 = 57.52$, $df = 9$) was found (see Table 5). This indicates there is a significant improvement in explanatory power of a one-factor model over that of the independence model. Further analysis looked at the difference between the χ^2 and degrees of freedom of the two research models. A significant difference was not found between the original factor structure (Sheslow & Adams, 1990) and that found by latter researchers (Burton, 1996; Wasserman & Cambias, 1991) ($\chi^2 = 5.97$, $df = 3$). This indicated there was no improvement in explanatory power from the factor structure obtained by reanalyzing the standardization data.

Table 5

Comparison of Each Confirmatory Factor Analysis

Models	χ^2 difference	df difference	critical value
N1 – N2	57.52	9	16.919*
N1 – X1	67.07	10	18.307*
N1 – X2	73.19	10	18.307*
N2- X1	9.55	9	16.919
N2 –X2	15.52	9	16.919
X1- X2	5.97	3	7.815

Note. N1 = Null 1 where all subtests stand alone; N2 = Null 2 where all subtests load on one factor; X1 = Sheslow and Adam's original factor structure; X2 = Wasserman and Cambias'/Burton et al. structure. *p = .05.

Comparison of the research models to each null model was next made. A significant difference was found when comparing the model obtained by Sheslow and Adams (1990) to Null 1 ($\chi^2 = 67.07$, $df = 10$). A significant difference was also found when comparing the second research model (Burton et al., 1991; Wasserman & Cambias, 1996) to the Null 1 model ($\chi^2 = 73.19$, $df = 10$). This indicated there is significant improvement in explanatory power when a three factor structure was utilized over a model in which all subtests stood alone. The research models were next compared to the Null 2 model. No statistical difference was found between the one-factor model (Null 2) and the original factor structure ($\chi^2 = 9.55$; $df = 9$), nor between Null 2 and the second

research model ($\chi^2 = 15.52$, $df = 9$). This indicated there was no improvement in explanatory power from a one-factor model to a three-factor model.

Hypothesis 2

The second hypothesis predicted SAT math scores would be significantly positively correlated with spatial relations scores. No support for this hypothesis was found using a one-tailed Pearson R correlation ($r = .204$).

Additional Research Questions

The first analysis looked at whether ethnicity had an effect on WRAML scores, mechanical reasoning ability or spatial relations skill. Because of low cell size, subjects were placed in either white or non-white categories (white = 42; non-white = 22). Independent sample t-test analyses were utilized. When looking at ethnicity in relation to spatial relations and memory scores, no significant differences were found for spatial relations [$t(62) = -1.18$, $p > .05$]; Visual Memory Index [$t(62) = -.22$, $p > .05$]; Verbal Memory Index [$t(62) = -1.05$, $p > .05$]; Learning Index [$t(62) = -.25$, $p > .05$]; or General Memory Index [$t(62) = , p > .05$]. See Table 6 for mean scores. However, because mechanical reasoning violated the assumption of homogeneity of variance, a nonparametric analysis was used. While the Mann-Whitney analysis approached significance ($p = .051$), further testing utilizing an equal and larger sample size is warranted.

Independent sample t-tests were next used to look at whether gender had an effect on WRAML scores, mechanical reasoning, or spatial relations. A significant difference

Table 6

Breakdown of Mean Scores between White and Non White

	White	Non White
Verbal Memory Index	107.77	111.02
Visual Memory Index	106.55	107.24
Learning Index	113.64	114.36
General Memory Index	111.77	113.12
Mechanical Reasoning	55.27	58.74
Spatial Relations	50.09	52.00

was found for mechanical reasoning [$t(62) = 2.98, p < .01$] and spatial relations [$t(62) = .28, p < .05$]. No significant difference between means was found for Visual Memory Index [$t(62) = -.81, p > .05$]; Verbal Memory Index [$t(62) = -1.334, p > .05$]; Learning Index [$t(62) = -1.85, p > .05$]; or General Memory Index [$t(62) = -1.59, p > .05$]. See Table 7 for mean scores.

A final exploratory analysis was conducted looking at the ability of mechanical reasoning, spatial relations, visual memory, and verbal memory for predicting academic success (defined as total GPA). A standard multiple regression was performed between mechanical reasoning, spatial relations, visual memory, and verbal memory as independent variables and GPA as the dependent variable. No combination of variables was found to be statistically significant in predictive ability (see Table 8). A simple

regression was also conducted on each independent variable. No single variable was found to be statistically significant in predicting GPA (see Table 8).

Table 7

Breakdown of Mean Scores between Male and Female

	Male	Female
Verbal Memory Index	107.68	111.64
Visual Memory Index	105.64	108.06
Learning Index	111.25	116.33
General Memory Index	110.11	114.64
Mechanical Reasoning	53.29*	49.83*
Spatial Relations	60.00**	55.64**

* $p < .01$; ** $p < .05$.

Table 8

Model Summary of Regression Analyses

Model	R	R ²	Adjusted R ²	Std Err Of Estimate
MR, SP, VerMind, VisMind	.255	.065	.002	.5607
MR	.088	.008	-.008	.5636
SP	.129	.017	.001	.5610
VerMind	.056	.003	-.013	.5649
VisMind	.156	.024	.009	.5588

Note. MR = mechanical reasoning, SP = spatial relations, VerMind = verbal memory index, VisMind = visual memory index.

CHAPTER IV

DISCUSSION

Hypothesis One

This study failed to support the first hypothesis, which predicted the data obtained would fit into the factor structure obtained by Sheslow and Adams (1990). The results obtained in this study support the contention of researchers who question the construct validity of the Learning Index of the WRAML. In the WRAML manual, the test authors defined learning as “increases in memory which results as a function of repeated exposure to a fixed set of stimuli” (Sheslow & Adams, 1990, p. 13). They interpreted the Learning Index as a way to “allow the evaluation of a child’s memory strategies” (p. 14). However, it appears to be unclear as to whether the subtests in the Learning Index can differentiate between strategic memory processes and rote memory processes.

The subtests in the Learning Index present all information to be learned in the first trial. Three more opportunities are presented to determine a measure of retention over the consequent trials. A youth’s performance is reflected only in terms of a summary score, i.e., total recall across the four trials. This summary score does not reflect the nature of acquisition across trials. It has been argued, therefore, this score may not capture the true variance associated with the “learning” process per se (Gioia, 1991).

Only one subtest in this index, Verbal Learning, appears to present a set of unstructured information that may require a youth to strategically organize the material in

a meaningful manner in order to increase retention. The other two subtests, Sound Symbol and Visual Learning do not require such a cognitive strategy. These subtests present what may be termed “paired associates” (Burton et al., 1999) and appears to be a measure of verbal and nonverbal cued retrieval. The lack of needed cognitive strategies as well as the retrieval cues provided during recall trials on these two subtests may be what make these measures less strategic in nature. Others suggest had this strategic component been included in more than one subtest, a learning factor might have been empirically supported (Burton, et al., 1999).

It may be useful to determine if a strategic memory factor can be demonstrated in a child population. Aylward et al., (1995) recommended that the internal processing variables of the subtests, such as strategy use, learning curve, or consistency of recall, be defined and consequently examined using factor analysis so as to understand their relationship to the structure of children’s memory processing. Other tests could be used in combination with the WRAML, such as the California Verbal Learning Test for Children (CVLT-C) to address this issue. The CVLT-C was designed to provide a measure of children’s learning and mnemonic organizational abilities (Delis, Kramer, Kaplan & Ober, 1994). Others have suggested a combined WRAML/CVLT-C memory battery as way to provide evidence supporting a strategic memory/learning factor (Burton et al., 1999).

It has been argued from an information processing perspective, the separation of learning and memory into different measures is artificial and of questionable practice. Gioia (1991) contends that it may not be possible to separate these functions given that

acquisition/encoding, memory formation/storage, and retrieval are interdependent components along a common continuum. He and others (Delis et al., 1994) feel that learning/acquisition and memory/retention are directly related to each other and should be assessed and analyzed within the same measure.

Overall, the confirmatory factor analysis studies on the WRAML have supported the distinction between verbal and visual memory. Differing opinion lies as to the third factor. There has been support for the third factor being related to attention (Burton et al., 1996, 1999; Phelps, 1995; Wasserman & Cambias, 1992). For example, two particular subtests, number/letter memory and finger windows, have been found to be more strongly correlated with other attentional measures (Knox Cube Test and WISC-R Digit Span) than with subtests from their respective indexes (Haut et al., 1992). Several of the confirmatory factor analyses have grouped these two particular subtests together. Because the controversy surrounding the factor structure of the WRAML, further investigation into the relationship between attention and the WRAML subtests is warranted, particularly number/letter memory and finger windows.

It is well established that developmental differences exist along a number of learning and memory dimensions (Boyd, 1988; Schneider & Pressley, 1989). One criticism of the WRAML contends that the wide age range on the WRAML may ignore developmental differences in learning (Gioia, 1991). At the present time, there are only two age groups five to eight years, and nine years to 17.11 years. Closer year size groups (e.g., 5-7, 8-10, 11-13, 14-17) may produce very different factor structures, which could

provide an explanation for the lack of consistent findings regarding the factor structure of this memory instrument.

As discussed above the literature shows an attention-related factor has been found in the WRAML confirmatory factory analysis studies. It has been suggested that developmentally attention plays a much greater role in memory processes in younger children than in older teenagers (Haut et al., 1992). This also warrants separating subjects into smaller age groups as well as investigation as to what role attention plays within the factor structure of the WRAML.

Amos Structural Equation Modeling program from SPSS allows for the investigation of data into already defined factor models. Therefore, additional analysis looked at how the data fit three additional models. The first was a factor model found when the standardization data was reanalyzed. The second addressed the issue raised for clinical interpretation of the WRAML at the subtest level. Consequently a model having all subtests stand alone as independent factors was investigated. Since the data fit neither three-factor model nor the independence model, the last exploratory analysis looked at how the data would fit a one-factor model.

The data failed to fit any of the above mentioned models. However, it was of interest to see if there was an increase in explanatory power when going from the independence model to a one-factor model and/or a three-factor model. The comparison between the Null 2 model (one factor) and the Null 1 model (independence model) found a statistically significant difference. This finding indicated a significant increase in explanatory power of a one factor model over a model in which the subtests stood alone

as independent factors. However, when a comparison was made between the two research models, no significant difference was noted. This study found no support that the new factor structure obtained by reanalyzing the original standardization data (Burton et al, 1996; Wasserman & Cambias, 1991) was any more useful than the original factor obtained by the WRAML's authors (Sheslow & Adams, 1990).

It was of interest to note that when each research model was compared to the Null 1 model, a statistical difference was found. This indicated that both three factor models better explained the data than having all subtests stand alone as factors. However, when comparison was made between each research model and the Null 2 model, no statistical difference was found. There was no improvement in explanatory power from a one factor model to that of either three factor model. This finding adds to the growing body of literature that questions the rationale behind Sheslow and Adams' (1990) factor structure.

The lack of significant results may be a result of the limitations of this study. The most noteworthy limitation of this study is sample size. Sixty-four subjects were utilized which allowed for seven subjects for each of the nine variables. As previously discussed, chi-square is sensitive to sample size. As sample size decreases below 100, there is a tendency for nonsignificance even if a significant difference does exist. The recommended number of subjects is 100 to 200 for structural equation modeling (Hair et al., 1995). Consequently, using less than the recommended number of subjects from this particular subject pool may have altered the results obtained.

Another limitation of this study may be the actual subject pool itself, i.e., an academically talented group of adolescents. One of the main purposes of this study was

to see if the factor structure of the WRAML would be replicable utilizing a non-clinical population. This study fulfilled this purpose. However while the population was non-clinical in nature, it may not be representative of an average non-clinical sample in regards to memory ability. The literature addresses how the memory skills of gifted are generally believed to be enhanced in many areas, e.g., increased memory capacity, metamemory skills and encoding ability. However, verbal or visual memory ability for gifted population has not been specifically addressed in the literature. The division of specific memory skills such as verbal vs. visual may not be as distinct within a group of subjects generally believed to have overall increased memory abilities. Further study utilizing a nongifted non-clinical adolescent population is warranted.

Another limitation could be that all subjects were not tested at the same time in their academic program. All subjects were in their first year of the TAMS program. However, some subjects were tested during their first semester, while others were tested during the second semester. The results of those tested during their first semester may be biased by the stress of adjusting to their new surroundings, e.g., being away from home for the first time or lack of test-taking experience. Those testing during the second semester may have been more comfortable with the college setting and test taking in general since they would have been through their first set of final exams.

Hypothesis Two

The second hypothesis predicted SAT math scores would be significantly positively correlated with spatial relations scores. No support for this hypothesis was found conflicting with previous research which found mathematical talent to be

associated with spatial abilities (Benbow, 1988a, Benbow & Minor, 1990, Cohn, 1978; Dark & Benbow, 1990). The discrepancy may be explained by how “mathematically talented” was operationally defined. Benbow and Minor’s study (1990) included only those subjects whose SAT-M score was at least 700. Current SAT-M scores ranged from 600 to 800 with a mean of 672, a median of 660, and a mode of 640. In this study, 43 subjects had SAT-M scores of below 700 while 21 had scores of 700 and above. Perhaps those who are better in math (≤ 700 on SAT-M) include additional ability in spatial skill. Further study looking at different levels of math ability related to spatial skill may be warranted. Those who score higher on the SAT-M may do so because of additional ability in related areas.

Other research has also included more than one measure of spatial ability (Benbow & Minor, 1990; Dark & Benbow, 1990). Benbow and Minor (1990) included three measures of spatial ability. The first one measured the ability to perceive arrangements of items of visual information in space. The second one measured the ability to visually transform images. The transformations included changes in location or position, rearrangement of parts, or substitutions of one visual object for another. The final test measured the ability to form and manipulate mental images of objects. Current results may differ because a more comprehensive measure of spatial relations was not utilized. Only one measure of spatial ability was used which required a subject to choose which three-dimensional figure matched an unfolded two-dimensional figure. This may be a somewhat of a restricted measurement of spatial ability, which could account for the current lack of relationship between SAT-M and spatial relations skill found in this study.

Exploratory Analysis

This study looked at the effects of gender and ethnicity on a variety of factors, i.e., memory scores, mechanical reasoning ability, and spatial relations skill. Because there was not enough subjects in each specific ethnic group, all ethnic groups were collapsed in one category, i.e., non-white. Overall, ethnicity was not found to have any effect on these variables. However, the lack of significant results may be due to the small number of non-white subjects and unequal cell size (white = 42; non-white = 22). Further research is warranted utilizing a larger and equal sample size (e.g., 50 subjects in each ethnic group) in regards to investigating the effects of ethnicity on these variables.

Gender was found to have an effect on mechanical reasoning skills and spatial relations ability with males better than females. This is consistent with previous research for a non-gifted population (Bennett et al., 1990; Feingold, 1995, 1988; Maccoby & Jacklin, 1974; Stanley et al., 1992). However, this has not held consistent with a gifted population in regards to spatial relations ability. Weiner and Robinson (1986) found no gender differences among a group of gifted youth, however they attribute their results to a second component of spatial ability, spatial orientation. As previously discussed the spatial relations subtest on the DAT may be a limited instrument that only measures a small aspect of spatial relations ability. With this particular population, gender differences may disappear as more extensive measures of spatial relations skill are used.

It is generally believed the academically talented youth have the ability to perform above average in several areas, i.e., multipotentiality (Emmett & Minor, 1993; Kerr & Claiborn, 1991; Kerr & Colangelo, 1988; Kerr & Ghrist-Priebe, 1988; Milgram, 1991;

Silverman, 1993). Gender differences may not appear in particular skill domains however. A performance threshold may exist which reduces any statistical differences between scores of males vs. females. For example, Weiner and Robinson (1986) have shown a gender difference may no longer exist in regards to spatial relations skill in a gifted population. This study failed to replicate their results.

No significant differences were found when looking at the effect of gender on either verbal, visual, or general memory scores. This supports previous findings that have failed to find gender differences in memory (Maccoby & Jacklin, 1974; Temple & Cornish, 1993). However, Anooshian and Seibert (1996) point out that memory research has not typically included individual difference variables and they call for future research on memory to include individual difference variables such as gender, ethnicity, or motivation.

There is some research that supports female superiority in regards to memory (Born, Bleichrodt, & van der Fleir, 1987; Herlitz, Nilsson, & Backman, 1997). However, their work has been criticized because memory has not been measured in consistent ways (e.g., episodic memory vs. primary memory vs. working memory). It is also noted that where studies say they are measuring a certain type of memory (e.g., episodic memory), they do not operationally define the memory variable the same across studies (Anooshian & Seibert, 1996).

Lastly, this study looked at whether mechanical reasoning ability, spatial relations skill, visual memory, and verbal memory would be helpful in predicting academic success (defined as GPA). No combination of variables was found to be significant in

predicting those who succeed academically, nor was any single variable found to be significant in predictive ability.

Previous research has found verbal memory to be related to achievement in regards to an older group of adolescents (16-17 years) (Sheslow & Adams, 1990; Hainlen, 1994). These results indicated that as a child grows he or she tends to rely more on verbal memory strategies than visual. Results obtained in this study did not support these previous findings. Although the subjects in this study were in the same age group, verbal memory was found not to be helpful in predicting academic success. The discrepancy may be because this study used overall GPA as the measure of academic success, while the previous study used a combination of broad reading and math achievement scores from the Woodcock-Johnson Revised Tests of Achievement. The scores obtained on the achievement test reflect how much overall knowledge in an area has been learned thus far, while GPA reflects effort of learning specific course material. Although grades for individual courses were not part of the data set, looking at grades in particular classes may have produced different results.

At the present time, the Wide Range Assessment of Memory and Learning is a useful tool for child neuropsychologists given that it is well standardized and easy to administer to children between the ages of five and 17.11 years. Overall many feel it is the best available tool available for memory assessment of youth in this age range (Haut et al, 1992). Research has called into question the primacy of the composite scales as the first order of clinical interpretation. It has been argued because of higher specific factor loadings than common factor loadings on the majority of the subtests, the subtests as they

are, have less of an association with each other than they do as individual entities. This combined with the many failures to reproduce the original factor structure, call into question the validity of clinically interpreting the WRAML at the index level.

Overall this study had many limitations. The most noteworthy was sample size. Results may differ if a larger number of subjects (e.g., 100-200) were utilized. Sample size was also a problem when ethnicity was considered. Because there was not enough subjects to be placed in specific ethnic groups, all non-white subjects were grouped together. However, this did not significantly improve cell size. Other limitations include the particular subjects utilized in this study, i.e., an academically talented group. To date research has not addressed the issue of the memory abilities of the gifted particularly in the area of visual and verbal memory. Further research as to how these memory abilities differ from the non gifted may provide useful information in regards to utilization of the WRAML with this population. A test taking learning curve may also have limited the results of this study. Having all students tested at the same time in their academic program would alleviate this problem. To date this study is the first to look at the factor structure of the WRAML with a non-clinical population. However, because of the limitations of the study, further research with a large enough sample of non-clinical, non-gifted adolescents is warranted.

APPENDIX A

WRAML SUBTEST DESCRIPTION

Appendix A

WRAML Subtest Description

Verbal Memory Scale

Number/Letter Memory--The task requires repetition of a random mix of numbers and letters presented in strings of 2 to 10 units. The number and letter combination was chosen to prevent "chunking."

Sentence Memory--The child is asked to repeat meaningful sentences beginning with a three word sentence.

Story Memory--Two short stories are read and the child is asked to recall as many parts of the story as can be remembered.

Visual Memory Scale

Finger Windows--A card (the plain white side to the child) with 9 holes on it is held up in front of the child. The examiner then using coded random sequences (and the numbered side of the card) puts a pencil in 2 through 9 windows, progressively. The child is then asked to reproduce the spatial sequence by putting his or her finger through the holes in the order presented.

Design Memory--After a presentation of 5 seconds and a delay of 10 seconds, the child is asked to reproduce 4 designs.

Picture Memory--After viewing a complex meaningful scene for 10 seconds, the child is shown a similar scene and asked to make all the items that have been added or changed. Four sets of scenes are used.

Learning Scale

Verbal Learning--A list of 16 simple words is read to the child followed by immediate recall. Three additional presentation/recall trials follow.

Visual Learning--A board with 14 designs presented to the child. The designs are uncovered for one second each. The child is then presented with each design and asked to recall it's location on the board. The set of 14 designs are presented 4 times.

Sound Symbol--The child is asked to recall sounds associated with various abstract figures. There are 14 paired associates, and then after an initial "learning trial," they are presented/ recalled 4 times.

APPENDIX B

TABLE 9

Appendix B

Table 9

Correlation Matrix of WRAML Subtests - (9 & Older)

	PM	DM	VL	SM	FW	SS	SnM	VsL	NL
PM	1.00								
DM	.390	1.00							
VL	.233	.306	1.00						
SM	.315	.304	.353	1.00					
FW	.211	.247	.248	.244	1.00				
SS	.254	.283	.330	.374	.247	1.00			
SnM	.181	.223	.302	.435	.300	.352	1.00		
VsL	.294	.418	.301	.329	.272	.378	.234	1.00	
NL	.143	.156	.203	.235	.280	.306	.605	.198	1.00

PM = Picture Memory

DM = Design Memory

VL = Verbal Learning

SM = Story Memory

FW = Finger Widows

SS = Sound Symbol

SnM = Sentence Memory

VsL = Visual Learning

NL = Number Letter Memory

APPENDIX C

TABLE 10

Appendix C

Table 10

Coefficient Alpha Medians Across Age and Person Separation Statistics for WRAML

Subtests

Subtests	Cof. Al. Median	PS 8 & <	PS 9 +
Picture Memory	.80	.85	
Design Memory	.85	.92	
Verbal LearninG	.78	.79	.82
Story Memory	.86	.88	.87
Finger Windows	.81	.91	
Sound Symbol	.90	.86	.92
Sentence Memory	.87	.94	
Visual Learning	.88	.87	.88
Number/Letter	.87	.92	
Verbal Memory	.93	*	
Visual Memory	.90	*	
Learning Index	.91	*	
General Memory Index	.96	*	

*Figures not provided by manual.

REFERENCES

Ablard, K. E. & Mills, C. J. (1995). Implicit theories of intelligence and self-perceptions of academically talented adolescents and children. Journal of Youth and Adolescence, 25 (2), 137-148.

Achter, J. A., Lubinski, D., & Benbow, C. P. (1996). Multipotentiality among the intellectually gifted: "It was never there and already it's vanishing." Journal of Counseling Psychology, 43 (1), 65-76.

Ackerman, P. L. (1989). Individual differences and skill acquisition. In P.L. Ackerman, R. J. Sternberg, & G. Glaser (Eds), Learning and individual differences: Advances in theory and research (pp. 164-217). New York: Freedman.

Adams, W. V., & Sheslow, D. V. (1990). Wide Range Assessment of Memory and Learning. Wilmington, DE: Wide Range, Inc.

Adams, W., Sheslow, D., Robins, P., & Wilkinson, G. (1992). Memory ability in children with attention deficit disorder. Wilmington, DE: Jastak Associates, Inc.

Anastasi, A. (1988). Psychological testing (6th ed.). New York: Macmillan.

Anooshian, L.J., & Siebert, P. S. (1996). Conscious and unconscious retrieval in picture recognition: A framework for exploring gender differences. Journal of Personality and Social Psychology, 70 (3), 637-645.

Atkinson, R. C., & Shiffrin, R. M (1968). Human Memory: A proposed system and its control processes. In K. W. Spence and J. T. Spence (Eds.), The psychology of learning and motivation, Vol 2., pp. 90-191. New York: Academic Press.

Aylward, G. P., Gioia, G., Verhulst, S. J., & Bell, S. (1995) Factor structure of the Wide Range Assessment of Memory and Learning in a Clinical Population. Journal of Psychoeducational Assessment, 13, 132-142.

Bailey, D. B., Jr., & Harbin, G. L. (1980). Nondiscriminatory evaluation. Exceptional Children, 46 (8), 590-596.

Baldwin, A. Y. (1987a). Undiscovered diamonds. Journal for the Education of the Gifted, 10, 271-286.

Baldwin, A. Y. (1987b). I'm Black but look at me, I'm also gifted. Gifted Child Quarterly, 31, 180-185.

Barbe, W. B., & Milone, M. N. (1982). Modality characteristics of gifted children. The gifted child teacher. Mobile, AL: G/C/T Publishing.

Bennett, G. K., Seashore, H. G., & Wesman, A. G. (1990). The Fifth Edition Manual for the Differential Aptitude Tests. New York: The Psychological Corporation.

Benbow, C. P. (1988a). Sex differences in mathematical reasoning ability in intellectually talented preadolescents: Their nature, effects and possible causes. Brain and Behavioral Sciences, 11, 169-232.

Benbow, C. P. (1988b). Neuropsychological perspectives on mathematical talent. In L. K. Obler & D. Fein (Eds.), The Exceptional Brain: Neuropsychology of Talent and Special Abilities (pp. 48-29). New York: Guilford.

Benbow, C. P. (1988c). Sex differences in mathematical reasoning ability in intellectually talented preadolescents: Their nature, effects, and possible causes. Behavioral and Brain Sciences, 11, 169-183.

Benbow, C. P., & Minor, L. L. (1990). Cognitive profiles of verbally and mathematically precocious students: Implications for identification of the gifted. Gifted Child Quarterly, 34 (1), 21-26.

Bernal, E. (1990). The identification blues and how to cure them. CAG Communicator, 20 (3), 1, 27.

Best, J. B. (1995). Cognitive psychology (4th ed), pp. 151-157. St. Paul, MN: West Publishing Company.

Blatter, P. (1983). Training in spatial ability: A test of Sherman's hypothesis. Perceptual and Motor Skills, 57, 987-992.

Boomsma, D. I. (1990). Does every smart boy have a smart sister? Behavioral and Brain Sciences, 13 (1), 192.

Borkowski, J. G. (1990). "Small" gender differences on the SAT: A secenario about social origins. Behavioral and Brain Sciences, 13 (1), 190-191.

Bouchard, T. J., & Segal, N. L. (1990). Advanced mathematical reasoning ability: A behavioral genetic perspective. Behavioral and Brain Sciences, 13 (1), 191-192.

Bower, G. H. (1975). Cognitive psychology: An introduction. In W.K. Estes (Eds.), Handbook of learning and cognitive processes (Vol 1). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bower, G. H., & Hilgard, E. R. (1984). Theories of learning (5th ed.). Englewood Cliffs, N.J.: Prentice-Hall, Inc.

Boyd, T. (1988). Clinical assessment of memory in children: A developmental framework for practice. In M. G. Tramontana and S. R. Hooper (Eds.), Assessment issues in child neuropsychology, 177-201. New York: Plenum Press.

Boyd, T. A. (1990, August). Comments on the Wide Range Assessment of Memory and Learning (WRAML). Symposium: Assessing memory in children: A new test battery. Division 12, 98th Annual Convention of the American Psychological Association, Boston, MA.

Brounstein, P. J. & Holahan, W. (1987). Patterns of change in scholastic aptitude test performance among academically talented adolescents. Roeper Review, 10 (2), 110-116

Brown, A. (1975). The development of memory: Knowing, knowing about knowing, and knowing how to know. In H. W. Rees (Eds.), Advances in Child Development and Behavior, 10, 103-152.

Burton, D. B., Donders, J., & Mittenburg, W. (1996). A structural equation analysis of the Wide Range Assessment of Memory and Learning in the standardization sample. Child Neuropsychology, 2 (1), 39-47.

Burton, D. G., Mittenberg, W., Gold, S., & Drabman, R. (1999). A structural equation analysis of the Wide Range Assessment of Memory and Learning in a clinical sample. Child Neuropsychology, 5 (1), 34-40.

Callahan, T. S., Haut, J. S., Haut, M. S., & Franzen, M.D. (1993, August). Confirmatory factor analysis of the WRAML. Paper presented at the 101st annual meeting of the American Psychological Association, Toronto, Ontario, Canada.

Carr, M., & Borkowski, J. G. (1987). Metamemory in gifted children. Gifted Child Quarterly, 31 (1), 40-44.

Carroll, J. B. (1989). Intellectual abilities and aptitudes. In A. Lesgold & R. Glaser (Eds), Foundations for a psychology of education (pp. 137-197). Hillsdale, NJ: Erlbaum.

Casey, M. B., Nuttall, R., Pezaris, E., & Benbow, C. P. (1995). The influence of spatial ability on gender difference in mathematics college entrance test scores across diverse samples. Developmental Psychology, 31 (4), 697-705.

Cheng, P. W. (1993). Metacognition and giftedness: The state of the relationship. Gifted Child Quarterly, 37, 105-112.

Cohn, S. J. (1977). Cognitive characteristics of the top-scoring participants in SMPY's 1976 talent search. Gifted Child Quarterly, 22, 416-421.

Coleman, M. R., & Gallagher, J. J. (1992). State policies for identification of nontraditional gifted students. Gifted Child Today, 15, 17-17.

Cowan, N. (1988). Evolving conceptions of memory, selective attention, and their mutual constraints within the human information-processing. Psychological Bulletin, 104, 163-191.

Cox, J., & Daniel, N. (1983). Special problems and special populations: Identification. Gifted Child Today, 30, 54-61.

Craik, F. I., & Lockart, R. S. (1972). Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 11, 671-684.

Crano, W. D., & Johnson, C. D. (1991). Facilitating reading comprehension through spatial skills training. Journal of Experimental Education, 59 (2), 113-127.

Dalby, P. R., & Obrzut, H. E. (1991). Epidemiological characteristics and sequelae of closed head-injured children and adolescents: A review. Developmental Neuropsychology, 7 (1), 35-68.

Dark, V. J., & Benbow, C. P. (1990). Enhanced problem translation and short-term memory: Components of mathematical talent. Journal of Educational Psychology, 82 (3), 420-429.

Dark, V.J., & Benbow, C. P. (1991). Differential enhancement of working memory with mathematical versus verbal precocity. Journal of Educational Psychology, 83 (1) 48-60.

Davidson, G. R. (1982). Cultural variation in minority test performance. Australian Psychologist, 17 (2), 216-218.

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (1994). California Verbal Learning Test: Children's Version. San Antonio, TX: The Psychological Corporation.

Dodd, D. H., & White R. M., Jr. (1980). Cognition: Mental structures and processes. Boston: Allyn & Bacon.

Donders, J. (1993). Memory functioning after traumatic brain injury in children. Brain Injury, 7 (5), 431-437.

Dreyden, J. I. & Gallagher, S. A. (1989). The effects of time and direction changes on the SAT performance of academically talented adolescents. Journal for the Education of the Gifted, 12 (3), 187-204.

Dunn, R. (1983). Learning style and its relation to exceptionality at both ends of the spectrum. Exceptional Children, 49 (6), 496-506.

Ebbinghaus, H. (1885). Memory : A contribution to experimental psychology. H.A. Ruger and C. E. Bussenius (Trans.). New York: Columbia University Teacher's College, translated, 1913.

Embretson, S. E. (1994). Applications of cognitive design systems to test development. In C. Reynolds (Ed) Advances in cognitive assessment: An interdisciplinary perspective (pp. 107-135). New York: Plenum.

Embreston, S. E. (1996). Cognitive design principles and the successful performer: A study on spatial ability. Journal of Educational Measurement, 33 (1), 29-39.

Emmett, J. D., & Minor, C. W. (1993). Career decision-making factors in gifted young adults. Career Development Quarterly, 41, 350-366.

Fatemi, E. (1991 May 27). Reports show minorities over-represented in special education classes. Education USA, pp. 273-276.

Feingold, A. (1988). Cognitive gender differences are disappearing. American Psychologist, 43, 95-103.

Feingold, A. (1995). The additive effects of differences in central tendency and variability are important in comparisons between groups American Psychologist, 50, (1), 5-13).

Ford, D. Y., & Harris, J. J. III (1990). On discovering the hidden treasure of gifted and talented black children. Roeper Review, 13 (1), 27-32.

Franzen, M. D. (1990). Review of the Wide Range Assessment of Memory and Learning. Test Critiques, Volume IX. Test Corporation of America.

Fredrickson, R. H. (1979) Career development and the gifted. In N. Colangelo & R. T. Zaffran (Eds.), New voices in counseling the gifted (pp. 264-276). Dubuque, IA: Kendall/Hunt.

Fredrickson, R. H. (1986). Preparing gifted and talented students for the world of work. Journal of Counseling and Development, 64, 556-557.

Gallager, S. A. (1989). Predictors of SAT Mathematics Scores of Gifted male and gifted female adolescents. Psychology of Women Quarterly, 13, 191-203.

Gaultney, J. F., Bjorklund, D. F., & Goldstein, D. (1996). To be young, gifted, and strategic: Advantages for memory performance. Journal of Experimental Child Psychology, 61, 43-66.

Garrison, L. (1992). Professionals of the future: Will they be female? Will they be ethnically diverse? Roeper Review, 15 (3), 161-164.

Geary, D. C., & Brown, S. C. (1991). Cognitive addition: Strategy choice and speed of processing differences in gifted, normal, and mathematically disabled children. Developmental Psychology, 27 (3), 298-406.

Geffen, L. (1989). Different doctoral dissertation research on gifted. Roeper Review, 12 (2), 122-124.

Geiger, R. W. D. (1992). Personality characteristics of highly academically talented adolescents: Variations with verbal or mathematical ability. Unpublished doctoral dissertation. University of Georgia, Athens, GA.

Gioia, G. A. (1998). Re-examining the factor structure of the Wide Range Assessment of Memory and Learning: Implications for clinical interpretation. Assessment, 5 (2), 127-139.

Gordon, E. W., Miller, F., & Rollock, D. (1990). Coping with communicentric bias in knowledge production in the social sciences. Educational Researcher, 19, 14-19.

Gregory S., & Lee, S. (1986). Psychoeducational assessment of racial and ethnic minority groups: Professional implications. Journal of Counseling and Development, 64, 635-637.

Griggs, S. A., & Dunn, R. S. (1994). Selected case studies of the learning style preferences of gifted students. Gifted Child Quarterly, 28 (3), 115-119.

Guilford, A. M., Scheuerie, J., & Shonburn, S. (1981). Aspects of language development in the gifted. Gifted Child Quarterly, 25 (4), 159-163.

Gutkin, T. B., & Reynolds, C. R. (1980). Factorial similarity of the WISC-R for Anglos and Chicanos referred for psychological services. Journal of School Psychology, 18, 34-39.

Hadaway, N., & Marek-Schroer, M. F. (1992). Multidimensional assessment of the gifted minority student. Roeper Review, 15 (2), 73-77.

Hainlen, V. S. (1994). Memory and academic achievement in a middle-school population. Unpublished doctoral dissertation, Texas Woman's University.

Halstead, W. C. (1947). Brain and Intelligence. Chicago: Chicago University Press.

Hansen J. B., & Linden, K. W. (1990). Selecting instruments for identifying gifted and talented students. Roeper Review, 13 (1), 10-15.

Hattrup, K., & Schmitt, N. (1990). Prediction of trades apprentices' performance on job sample criteria. Personnel Psychology, 43, 453-466.

Haut, J.S., Haut, M. W., Callahan, T. S., & Franzen, M. D. (1992, November). Factor analysis of the Wide Range Assessment of Memory and Learning (WRAML) scores in a clinical sample. Paper presented at the 12 annual meeting of the National Academy of Neuropsychology; Pittsburgh, PA.

Haut, J.S., Haut, M. W., & Franzen, M. D. (1992, February). Assessment of an Attentional Component of the Wide Range Assessment of Memory and Learning (WRAML). Paper presented at the 20th annual meeting of the International Neuropsychological Society, San Diego, CA.

Haut, J. S., Robyn, M. W., Haut, M. W., & Kirk, K. S. (1995). Memory and executive functioning in adolescents with schizophrenia and ADHD. Paper presented at the 25th annual meeting of the International Neuropsychological Society, Orlando, Florida.

Haut, J. S., Williams, J., & Hendon, A. (1994). Memory and attention skills of children with neurological and psychiatric disorders: Implications for clinical utility of the WRAML. Paper presented at the 22nd annual meeting of the International Neuropsychological Society, Cincinnati, Ohio.

Hegarty, M., & Sims, V. K. (1994). Individual differences in mental animation during mechanical reasoning. Memory and Cognition, 22 (4), 411-430.

- Herlitz, A., Nilsson, L. G., & Bockman, L. (1997). Gender differences in episodic memory. Memory and Cognition, 25 (6), 801-811.
- Hoyenga, K. B. (1990). Some of the pathological assumptions in the sciences of gender. Behavioral and Brain Sciences, 13 (1), 194-196.
- Hudes, S., Saladino, A., & Miegler, D. (1977). Learning style subscales and self-concept among high achieving third graders. The Journal, 7, 7-10.
- Humphreys, L. G. (1979). The construct of general intelligence. Intelligence, 3, 105-120.
- Humphreys, L.G., Lubinski, D., & Yao, G. (1993). Utility of predicting group membership and the role of spatial visualization in becoming an engineer, physical scientist, or artist. Journal of Applied Psychology, 78 (2), 250-261.
- Jackson, N. E., & Butterfield, E. C. (1986). A conception of giftedness designed to promote research. In R. J. Sternberg & J. E. Davidson (Eds.), Conceptions of Giftedness (pp. 151-181). Cambridge: Cambridge University Press.
- Janos, P. M., & Robinson, N. (1985). Psychosocial development in intellectually gifted children. In F. D. Horowitz & M. O'Brian (Eds.), The gifted and talented: Developmental perspectives (pp. 149-195). Washington, D.C: American Psychological Association.
- Jepsen, D. A. (1979). Helping gifted adolescents with career exploration. In N. Colangelo & R. T. Zaffrann (Eds.), New voices in counseling the gifted (pp. 277-283). Dubuque, IA: Kendall/Hunt.

Just, M., & Carpenter, P. (1985). Cognitive coordinate systems: Accounts of mental rotation and individual differences in spatial ability. Psychological Review, 92, 137-172.

Kail, R. V. (1979). Use of strategies and individual differences in children's memory. Developmental Psychology, 15 (3), 251-255.

Kail, R., & Hagen, E. (1982). Memory in childhood. In B. Wolman, G. Stricker, S. Ellman, P. Keigh-Speigel, & D. Palermo (Eds.), Handbook of Developmental Psychology, 350-366. Englewood Cliffs, NJ: Prentice-Hall.

Kerr, B. A. (1981). Career education strategies for the fited. Journal of Career Education, 7, 318-324.

Kerr, B. A., & Claiborn, C. D. (1991). Counseling talented adults. Advanced Development, 3, 75-83.

Kerr, B. A., & Colangelo, N. (1988). The college plans of academically talented students. Journal of Counseing and Development, 67, 42-48.

Kerr, B. A. & Erb, C. (1991). Career counseling with academically talented students: Effects of a value-based intervention. Journal of Counseling Psychology, 38, 309-314.

Kerr, B. A., & Ghrist-Priebe, S. L. (1988). Intervention for mulitpotentiality: Effects of a career counseling laboratory for gifted high school students. Journal of Counseling and Development, 66, 366-369.

Kitzen, K. (1983). Math and the dyslexic: Making the abstract concrete. New York: Suffolk Branch-Orton Dyslexia Society. (ERIC Document Reproduction Service No. ED240823).

Kolb, B., & Whishaw, I. Q. (1987). Fundamentals of human neuropsychology: 2nd Edition, pp. 475-512. New York: W. H. Freeman & Company.

Korchin, S. J. (1980). Clinical psychology and minority problems. American Psychologist, 35, 262-269.

Kontos, S., Swanson, H. L., & Frazer, C. T. (1984). Memory-metamemory connection in intellectually gifted and normal children. Psychological Reports, 54, 930.

Kovac, J. (1989). The validation of selected spatial ability tests via correlational assessment and analysis of user-processing strategy. Educational Research Quarterly, 13 (2), 26-34.

Kurtz, B. E., & Weinert, F. E. (1989). Metamemory, memory performance, and casual attributions in gifted and average children. Journal of Experimental Child Psychology, 48, 45-61.

Levin, H., Mattis, S., Ronald, R., Eisenberg, H., Marshall, L., Tabbaddor, K., High, W., & Frankowski, R. (1987). Neuro-behavioral outcome following minor head injury: A three-center study. Journal of Neurosurgery, 66, 234-243.

Lovecky, D. V. (1994). Exceptionally gifted children: Different minds. Roeper Review, 17 (2).

Lubinski, D., & Benbow, C.P. (1994). The study of mathematically precocious youth: The first three decades of a planned 50-year study of intellectual talent. In R. F.

Subotnik & K. D. Arnold (Eds.), Beyond Terman: Contemporary longitudinal studies of giftedness and talent (pp. 255-281). Norwood, NJ: Ablex.

Luria, A. R. (1973) The working brain. Basic Books.

Maccoby, E. E., & Jacklin, C. H. (1974). The psychology of sex differences. Stanford, CA: Stanford University Press.

Maker, C. J. (1982). Curriculum development for the gifted. Rockville, MC: Aspen.

Marshall, B. C. (1981). Career decision making patterns of gifted and talented adolescents: Implications for career education. Journal of Career Education, 7, 305-310.

Marx, M. H. (1992). Development of inferences over elementary-school grades: III. Verbatim and forward-consequence inferential errors made by regular and gifted students. Bulletin of the Psychonomic Society, 30 (5), 353-355.

McKenzie, J. (1986). The influence of identification practices, race, and SES on the identification of gifted students. Gifted Child Quarterly, 30, 93-95.

Mealer, C. Z. (1994). The validity of the WRAML and WISC-III in differentiating ADHD boys, clinic-referred boys, and non-clinic referred boys. Unpublished doctoral dissertation, Texas Woman's University.

Milgram, R. M. (Ed.). (1991). Counseling gifted and talented children: A guide for teachers, counselors and parents. (pp. 121-138). Norwood, NJ: Ablex.

Miller, K., Perimutter, M. & Keating, D. (1984). Cognitive arithmetic: Comparison of operations. Journal of Experimental Psychology, Learning, Memory and Cognition, 10, 46-60.

Novick, M. R. (1981). Federal guidelines and professional standards. American Psychologist, 36, 1-35-1046.

O'Boyle, M. W., Alexander, J. E., & Benbow, C. P. (1991). Enhanced right hemisphere activation in the mathematically precocious: A preliminary EEG investigation. Brain and Cognition, 17, 138-153.

O'Boyle, M. W., & Benbow, C. P. (1990). Enhanced right hemisphere involvement during cognitive processing may related to intellectual precocity. Neuropsychologia, 28, 211-216.

O'Boyle, M. W., Gill, H. S., Benbow, C. P., & Alexander, J. E. (1994). Concurrent finger-tapping in mathematically gifted males: Evidence for enhanced right hemisphere involvement during linguistic processing. Cortex, 30, 519-526.

Olmedo, E. L. (1981). Testing linguistic minorities. American Psychologist, 36, 1035-11085.

Olszewski-Kubilius, P M., Kulieke, M. H., & Krasney, N. (1988). Personality dimensions of gifted adolescents: A review of the empirical literature. Gifted Child Quarterly, 32, 347-352.

Orlofsky, J. L. (1981). A comparison of projective and objective fear of success and sex role orientation measures as predictors of women's performance on masculine and feminine tasks. Sex Roles, 7, 999-1018.

Paivio, A. (1969). Mental imagery in associative learning and memory. Psychological Review, 76, 241-263.

Paivio, A. (1971). Imagery and verbal processes. New York: Holt, Rinehart, & Winston.

Paivio, A., & te Linde, J. (1982). Imagery, memory, and the brain. Canadian Journal of Psychology, 26 (2), 243-272.

Pennett, H. D. (1994). Characteristic memory functions in subtypes of arithmetic disabled children. Unpublished doctoral dissertation, University of North Texas.

Peterson, A. C., Crockett, L. J., & Graber, J. (1990). Issues in the development of mathematical precocity. Behavioral and Brain Sciences, 13 (1), 192-193.

Phelps, L. (1995). Exploratory factor analysis of the WRAML with academically at-risk students. Journal of Psychoeducational Assessment, 13, 384-390.

Pletan, M. D., Robinson, N. M., Berninger, V. W., & Abbott, R. D. (1995). Parents' observations of kindergartners who are advanced in mathematical reasoning. Journal for the Education of the Gifted, 199 (1), 30-44.

Reis, S. M., & Renzulli, J. S. (1982). A case for a broadened conception of giftedness. Phi Delta Kappan, 63, 619-620.

Rogers, K. (1986). Do the gifted think and learn differently? A review of recent research and its implications of instructions. Journal for the Education of the Gifted, 10, 17-39.

Rhodes, L. (1992) Focusing attention on the individual in identification of gifted black students. Roeper Review, 14, 108-110.

Romberg, D. L., & Shore, M. F. (1986). A test of two hypotheses of fear of success. Sex Role, 14, 163-180.

Saccuzzo, D. P., Johnson, N. E., & Guertin, T. L. (1994). Information processing in gifted versus non-gifted African American, Latino, Filipino, and White Children: Speeded Versus Non-speeded paradigms. Intelligence, 19, 219-243.

Sanborn, M. P. (1979a). Career development: Problems of gifted and talented students. In N. Colangelo & R. T. Zaffrann (Eds.), New voices in counseling the gifted (pp. 284-300). Dubuque, IA: Kendall/Hunt.

Sanborn, M. P. (1979b). Counseling and guidance needs of the gifted and talented. In A. H. Passow (Ed.), The gifted and talented: Their education and development (pp. 424-428). Chicago: University of Chicago Press.

Scheuneman, J. (1979). A method of assessing bias in test items. Journal of Educational Measurement, 16 (3), 143-152.

Schneider, W., & Pressley, M. (1989) Memory development between 2 and 20. New York: Springer-Verlag.

Scoville, W. B., & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. Journal of Neurology, Neurosurgery, and Psychiatry, 20, 11-21.

Sheslow, D. & Adams, W. (1990). Wide Range Assessment of Memory and Learning administration manual. Wilmington, DE: Jastak Associates, Inc.

Shiffrin, R. M., & Atkinson, R. C. (1969). Storage and retrieval processes in long-term memory. Psychological Review, 76 (2), 179-193.

Siegler, R. S., & Kotovsky, K. (1986). Two levels of giftedness: Shall ever the twain meet? In R. J. Sternberg & J. E. Davidson (Eds.), Conceptions of Giftedness (pp. 417-435). Cambridge: Cambridge University Press.

Silverman, L. K. (Ed.). (1993). Counseling the gifted and talented. Denver, CO: Love.

Snook, S. C., & Gorsuch, R. L. Principal component analysis versus common factor analysis: A Monte Carlo study. Psychological Bulletin, 106, 148-154.

Snow, R. E., & Lohman, D. F. (1989). Implications of cognitive psychology for educational measurement. In R. L. Linn (Ed.), Educational measurement (3rd ed., pp. 263-331). New York: Collier Macmillan.

Solso, R. L., & Short, B. A. (1979). Color recognition. Bulletin of the Psychonomic Society, 14 (4), 275-277.

Squire, L. R. (1987). Memory and brain. New York: Oxford University Press.

Stanley, J. C., Benbow, C. P., Bordy, L. E., Dauber, S., & Lupkowski, J. (1992). Gender differences in eighty-six nationally standardized aptitude and achievement tests. In N. Colangelo, S. G. Asoulini, & D. L. Ambrison (Eds.), Talent Development, Vol. 1: Proceedings from the 1991 Henry B. and Jocelyn Wallace National Research Symposium on Talent Development (pp. 42-65). Unionville, NY: Trielium Press.

Sternberg, R. J. (1981). A componential theory of intellectual giftedness. Gifted Child Quarterly, 25, 86-93.

Sternberg, R. J. (1986). Identifying the gifted through IQ: Why a little bit of knowledge is a dangerous thing. Roeper Review, 8, 143-146.

Tabachnick, B. G., & Fidell, L. S. (1989). Using multivariate statistics, 2nd ed. New York, NY: Harper Collins Publishers, Inc.

Telzrow, C. F. (1987). Management of academic and educational problems in head injury. Journal of Learning Disabilities, 20, 536-545.

Temple, C. M., & Cornish, P.J. (1993). Recognition memory for words and faces in school children: A female advantage for words. British Journal of Developmental Psychology, 11, 421-426.

Thomas, H. (1993). A theory explaining sex differences in high mathematical ability has been around for some time. Behavioral and Brain Sciences, 16 (1), 187-189.

Tresemmer, D. (1976). The cumulative record of research on “fear of success.” Sex Roles, 2, 217-236.

Tresemmer, D. (1977). Fear of success. New York: Plenum.

United States Department of Education. (1989). No gifted wasted: Effective strategies for educating highly able, disadvantaged students in mathematics and science. Washington, DC: Government Printing Office.

Van Tassel-Baska, J., Patton, J., & Prillaman, D. (1989). Disadvantaged gifted learners: At risk for educational attention. Focus on Exceptional children, 22 (3), 1-15.

Waldron, K. A., & Saphire, D.G. (1992). Perceptual and academic patterns of learning-disabled/gifted students. Perceptual and Motor Skills, 74, 599-609.

Wang, L. (1995, October). Differential aptitude tests (DAT). Measurement and Evaluation in Counseling and Development, 28, 168-170.

Wasserman, J. D. & Cambias, R. D. (1992). Unpublished manuscript. Clinical Guidelines for Use with the WRAML.

Weiner, N. C., & Robinson, S. E. (1986). Cognitive abilities, personality and gender differences in math achievement of gifted adolescents. Gifted Child Quarterly, 30 (2), 83-87.

Wheaton, P. A. (1994). An evaluation of memory using the WRAML and Woodcock-Johnson Revised Test of Cognitive Ability. Unpublished doctoral dissertation, Texas Woman's University.

Whitaker, D. (1993). The WRAML: Initial impressions. Child Assessment News, 3, 1-5.

Wickens, C. D. (1984). Engineering psychology and human performance. Columbus, OH: Merrill Publishing.

Willingham, W. A., Rock, D. As., & Pollack, T. (1991). Predictability of college grades: Three tests and three national samples. In W. W. Willingham, C. Lewis, Morgan, R., and Ramist, L. (Eds.), Predicting college grades: An analysis of institutional trends over two decades, pp. 239-252. Princeton, NJ: Educational Testing Service.

Woods, S. B., & Achey, V. H. (1990). Successful identification of gifted racial/ethnic group students without changing classification requirements. Roeper Review, 13, 21-26.